H.F. Antenna Analysis

Dr. John A. Allocca, WB2LUA, 2004

Theoretical Antenna Patterns

1/2 Wave Horizontal Dipole Antenna - 7 MHz

Height (feet)	Take Off Angle (deg)
17.2	90
34.4	61
51.6	38
68.8	28
86.0	22
103.2	19
120.4	16
137.6	14

Maximum gain (5.89 db) is obtained at 59 degrees.

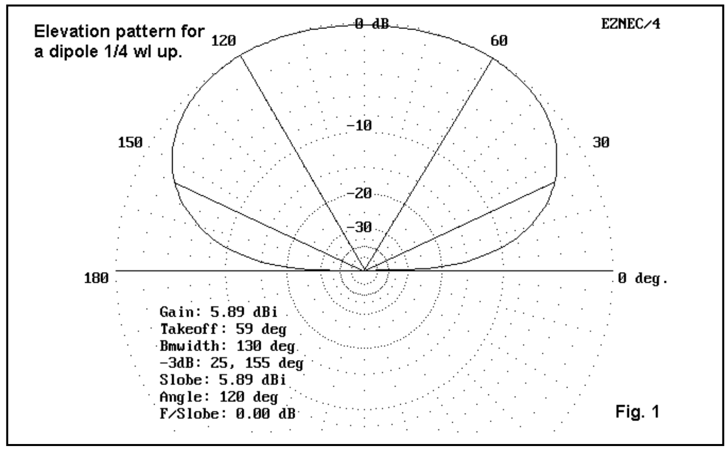


Fig. 1

Yagi Horizontal Antenna – 7 MHz

Height (feet)	Take Off Angle (deg)
17.2	58
34.4	45
51.6	34
68.8	27
86.0	22
103.2	18
120.4	16
137.6	14

Maximum gain (8.40 db) is obtained at 44 degrees.

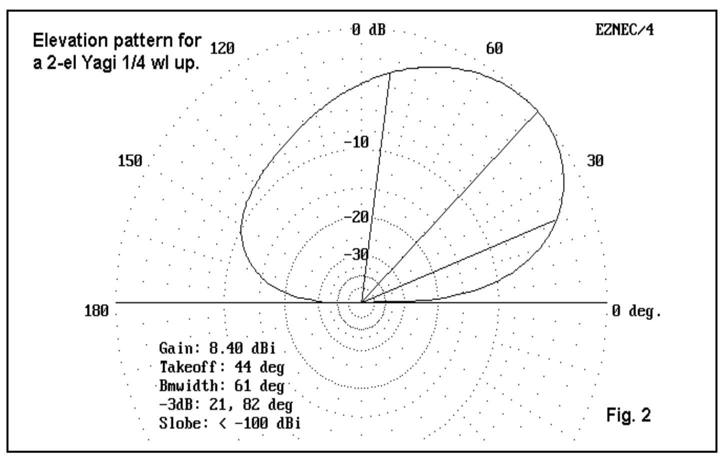


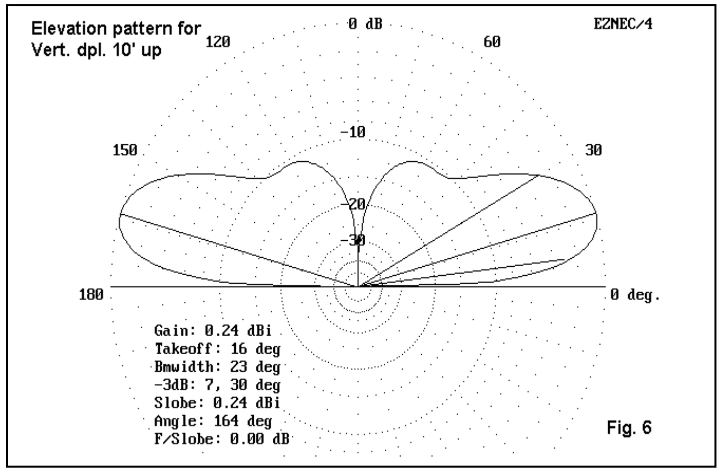
Fig. 2

The Yagi improvement in elevation angle is mostly at the lowest heights. Above a half-wavelength, the take-off angle closely matches that of the dipole. The Yagi exhibits about 3 dB more gain than the dipole at the angle of maximum radiation, which is 44 degrees.

The Vertical Dipole Antenna – 7 MHz

10' off the ground at lowest point
Feed point = 44'
Top = 78'

Maximum gain (0.24 db) is obtained at 16 degrees.



1/4 Wave Vertical Antenna Counterpoise

Band (meters)	Length (meters)	Length (feet)
10	2.5	8.2
12	3	9.84
15	3.75	12.3
17	4.25	13.94
20	5	16.4
30	7.5	24.6
40	10	32.8
60	15	49.2
80	20	65.6
160	40	131.2

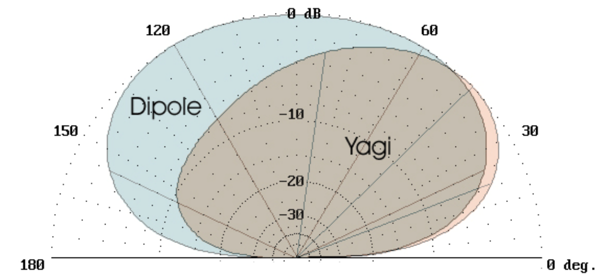
1/2 Wave Vertical Antenna Counterpoise

Band (meters)	Length (meters)	Length (feet)
10	5	16.4
12	6	19.68
15	7	22.96
17	8.5	27.88
20	10	32.8
30	15	49.2
40	20	65.6
60	30	98.4
80	40	131.2
160	80	262.4

Feet = 3.28 meters

Comparison of 1/2 Wave Horizontal Dipole and Yagi Antennas - 7 MHz

- Horizontal dipole
- Horizontal Yagi



1/2 Wave Horizontal Dipole and Yagi

Fig. 9

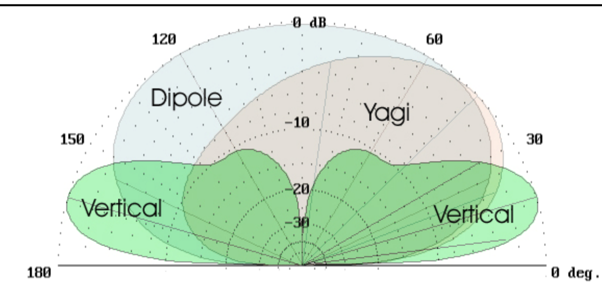
The horizontal dipole's maximum gain (5.89 db) is obtained at 59 degrees.

The horizontal Yagi's maximum gain (8.40 db) is obtained at 44 degrees.

The Yagi has slightly more gain in the lower angles of radiation. The horizontal dipole has a wider range.

Comparison of 1/2 Wave Horizontal Dipole, Yagi, and Vertical Antennas - 7 MHz

- Horizontal dipole
- Horizontal Yagi
- Vertical Dipole



1/2 Wave Horizontal Dipole, Yagi, Vertical

Fig. 10

The horizontal dipole's maximum gain (5.89 db) is obtained at 59 degrees.

The horizontal Yagi's maximum gain (8.40 db) is obtained at 44 degrees.

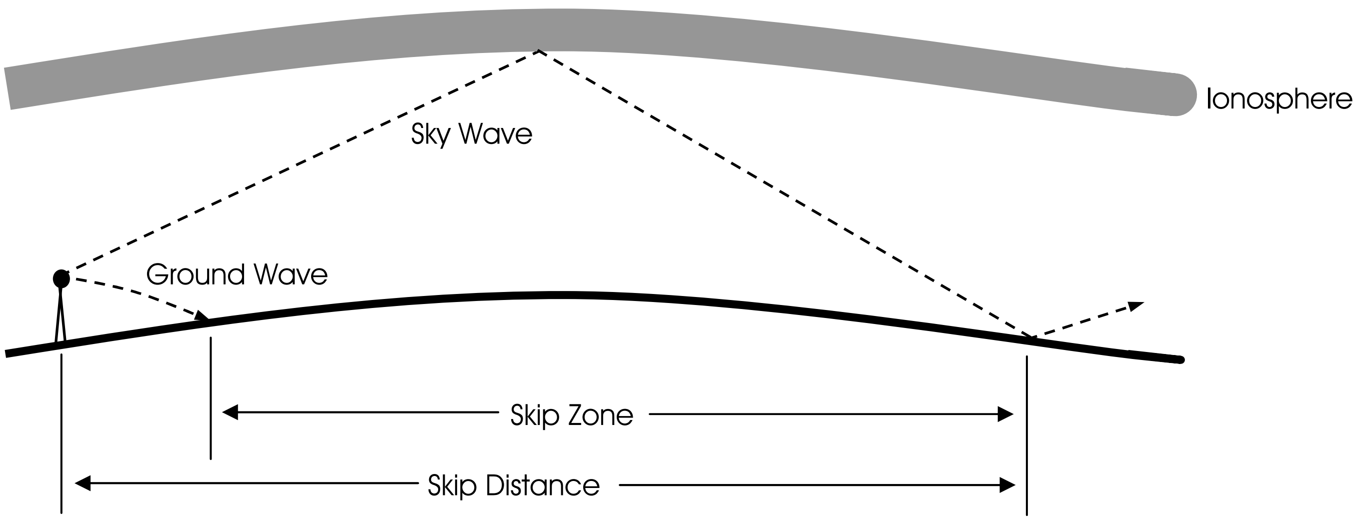
The vertical's maximum gain (0.24 db) is obtained at 16 degrees.

The horizontal dipole has the widest overall coverage.

The Yagi offers slightly more gain at slightly lower radiation angle than the horizontal dipole.

The vertical has more gain at lower radiation angles, excellent for long-range transmission.

Skip Distance, Skip Zones, and "Take Off" Angles of Radiation



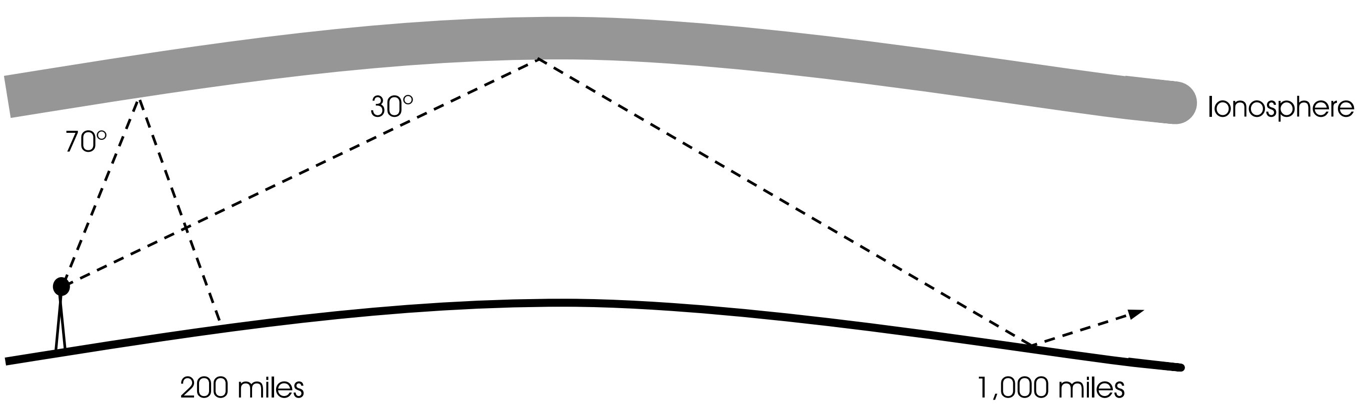
Antennas produce ground waves and sky waves.

A sky wave is a signal that travels toward the ionosphere and is reflected back down to earth. HF sky waves typically travel 100 to 8,000 miles. VHF sky waves typically travel 50 to 150 miles. The angle at which the sky wave is sent from the antenna to the ionosphere is called the "take off angle of radiation." The angle of radiation or take off angle is dependent upon the antenna type, the height of the antenna, and the frequency of the electromagnetic wave.

A ground wave is a signal that runs along the Earth's surface. It extends out from the antenna for up to about 50 miles. It is a limited signal, which allows for short distance communication.

A skip zone is an area where no signals will be received. Skip zones are formed when the nearest point at which a sky wave is received is beyond the furthest point at which a ground wave is received. When the ground wave coverage is great enough or the skip distance is short enough that no zone of silence occurs, there is no skip zone.

The ionosphere will reflect frequencies from 0.1 to 30 MHz.



Empirical Data

<u>Nassau Amateur Radio Club</u>
<u>Skip Zone (one hop) as a Function of Radiation Angle – 7 - 14 MHz. 2-3 element Yagi</u>

Height (feet)	Take Off Angle (deg)	Skip Zone F2 Layer (miles)	Miles Skipped
20	45	400-800	400
*27	40	450-900	450
*29.5	35	675-975	300
*32	30	650-1,300	650
37	20	950-1,700	750
45	15	1,200-2,000	800
50	12	1,300-2,300	1,000
60	10	1,400-2,400	1,000

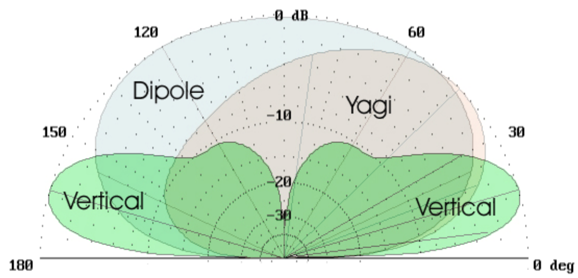
* Best suited for Field Day. Skip distance is about 1,500 miles, which allows optimum coverage of the East coast where most of the Field Day contacts are. It would also still allow one hop coverage to the West coast (about 6 to 10 db down for a 2 or 3 element Yagi), with a double hop zone of about 12 to 18 db down due to multi-skip losses over mid US terrain.

<u>Nassau Amateur Radio Club</u>
<u>Skip Zone (one hop) as a Function of Radiation Angle – 21 - 28 MHz. 2-3 element Yagi</u>

Height (feet)	Take Off Angle (deg)	Skip Zone F2 Layer (miles)	Miles Skipped
10	45	400-800	400
*13.5	40	450-900	450
*14.8	35	675-975	300
*16	30	650-1,300	650
18.5	20	950-1,700	750
22.5	15	1,200-2,000	800
25	12	1,300-2,300	1,000
30	10	1,400-2,400	1,000

* Best suited for Field Day. Skip distance is about 1,500 miles, which allows optimum coverage of the East coast where most of the Field Day contacts are. It would also still allow one hop coverage to the West coast (about 6 to 10 db down for a 2 or 3 element Yagi), with a double hop zone of about 12 to 18 db down due to multi-skip losses over mid US terrain.

Selecting an H.F. Antenna for Field Day



1/2 Wave Horizontal Dipole, Yagi, Vertical

Fig. 10

As indicated in Figure 10 above, the 1/2 wave vertical antenna will produce very good long-range communications because of its low angle of radiation. The 1/2 wave horizontal Yagi antenna will produce good long-range communications because it has slightly more gain in one direction and it has a lower angle of radiation. It also has much less gain in the reverse direction. The 1/2 wave horizontal dipole antenna will produce the best overall communications near and far because it has a wide angle of radiation in the forward and rear directions.

The horizontal 1/2 wave dipole will be chosen for use at Field Day because it has the best overall communications near and far. Most clubs are currently using dipole antennas for Field Day for the obvious reasons. As a secondary antenna, the Outbacker Outreach, which has been used in past Field Days, will continue to be used since it only takes a few minutes to set up. The Outbacker antenna is used by FEMA, U.S. Coast Guard, other military organizations, embassies and more.

There are two basic types of dipole antennas. The simple wire type that can be strung between two trees or a rigid aluminum tubing rotatable 1/2 wave dipole such as the Cushcraft D3 (10, 15, 20 meter) tri-band antenna. The rotatable dipole will facilitate communications in any direction by turning the mast. Either of these dipoles will provide excellent communications. . The Van Gorden wire dipoles have factory-installed balums. The Van Gorden D-20 (20 meter) wire dipole measures 33 feet in length.

Masts are available in many sizes and shapes. The Cushcraft D3 antenna weights only 9 pounds. Therefore a tower is not necessary. The mast can be rotated manually. Therefore, a 115 VAC powered rotator is not required. Furthermore, if there was an emergency, 12 volts may be the only power available. A mast of 24 feet can be constructed from 1-1/4" thick-wall (0.065") aluminum tubing and a public address speaker stand. A special guy ring can be made to allow the mast to be turned. There are also a number of different masts that can be obtained commercially or as military surplus.

Cushcraft D3 – 25.8 feet long

Mast and Antennas for Field Day & Emergencies

This is a 27 feet 1.5" diameter portable guyed mast with a 28 feet diameter footprint. It breaks down into four 6 feet sections plus the tripod. The total weight of the mast and tripod is 15 pounds. The homemade 1/4 wave dipole antenna weighs 3 pounds. The Cushcraft D3 antenna weighs 9 pounds. The mast can rotate even when guyed because of the special slip ring that is constructed.

Mast Construction - Step 1

Cut the 1/8" x 4" x 12" aluminum plate to 1/8" 4" x 4". Drill a 1.75" hole in the center. Drill 3/8" holes as shown in Figure 1 and figure 2. File all burrs.

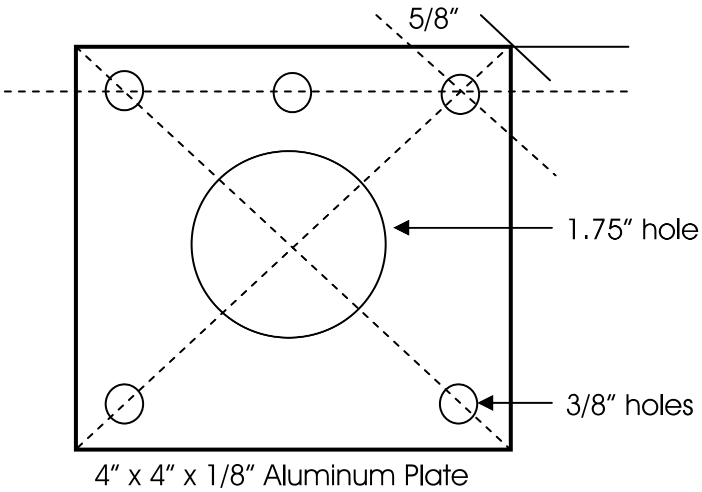


Figure 1

Mast Construction - Step 2

Position the nylon shaft collar and tighten the set screw. Remove the set-screw and drill a 9/32" hole at the mark. Re-insert the set-screw and tighten. Add the nylon washer and silicon grease as shown in figure 3. Add the second nylon shaft collar and tighten the set screw. Remove the set-screw and drill a 9/32" hole at the mark. Add the 4" x 4" plate. Re-insert the set-screw and tighten as shown in figure 4 and figure 5. Rings for the guy ropes will be placed on the guy ring later. Three or four rings and guy ropes can be used.

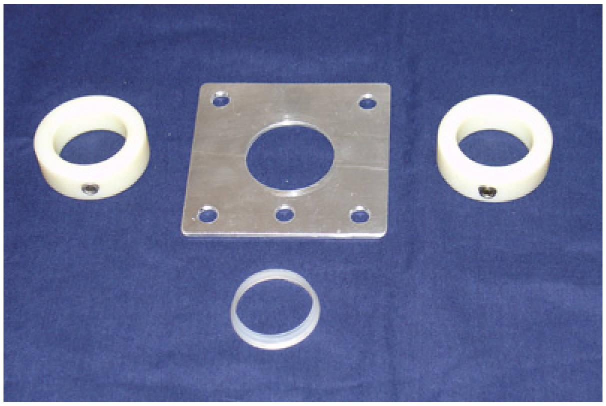


Figure 2

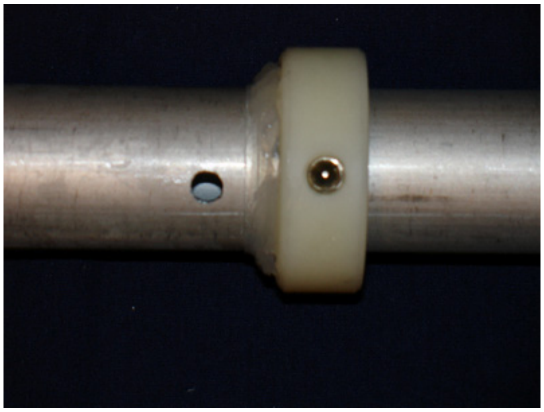


Figure 3

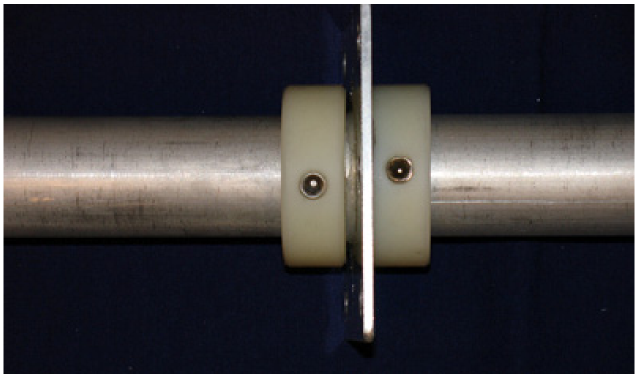


Figure 4

Figure 5

Mast Construction - Step 3

Cut six 1.5" x 1.5" 90 degree aluminum pieces, 12 inches long. Drill four 5/16" holes, 1.5" and 4.5" from each end. Insert one 1.5" x 6 feet aluminum tube into the center. Drill 5/16" holes through the aluminum angles and through the aluminum tube as shown in figure 6. Place two 1/4-20 x 3" screws, washers and hex nuts through both pieces and tighten with a wrench. Repeat for the other end except use wing nuts in place of hex nuts so it can be disassembled easily. Repeat this process for the other two sections.

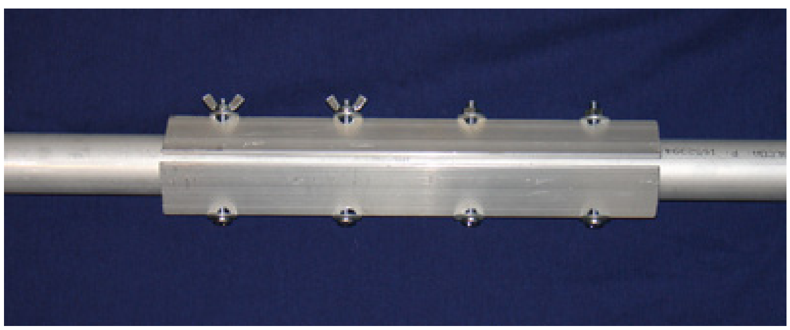


Figure 6

Mast Construction - Step 4

Drill an 11/32" hole, 12 inches from the end of the bottom mast section so that the lock pin can be inserted as shown in figure 7.

Figure 7

1/4 Wave Dipole Antenna Construction

Cut a 21-inch length of 1.5” PVC pipe. Drill two 3/8” holes and insert coax cable, soldier lugs, bolt, lock washers, and 3/8-24 coupling nuts. Drill two 5/16” holes for mounting it to the mast as shown in figure 8. Drill a 1/4" hole on the bottom and secure the coax cable with a wire tire as shown in Figure 9 and figure 10. Drill holes in the top section of the mast so that the antenna can be attached. Tune two hamsticks with an antenna analyzer. Attach the two hamsticks to the coupling nuts.

1/4 Wave Dipole Antenna Test Results

With the 20 meter dipole at a height of 24 feet, facing East and West from Northport, NY (altitude 187 feet), 5x9 reports were received from North Carolina, Georgia, Texas, and Pennsylvania. With the dipole facing North and South, 5x9 reports were received from as far as Argentina, South America. Propagation conditions were poor during this test (July 9, 2005).

Figure 8

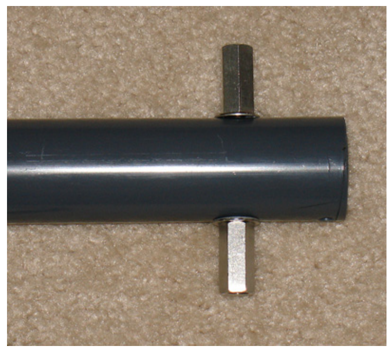


Figure 9

Figure 10

Finally Assembly

Assemble all components. Attach the guy rings and 1/4" nylon rope. Tighten the clamp on the tripod. Place a 6 feet piece of wood against the tripod legs so that it will not slip when the mast is hoisted upward. Attach either the 1/4 wave dipole antenna or the Cushcraft 1/2 wave D3 dipole antenna as shown in figure 13. Place three stakes in the ground 14 feet from the mast as show in figure 14. If the D3 antenna is used, have one person lift the antenna while another person pulls on the guy rope. Once the mast and antenna are in place, tighten the guy ropes. Loosen the clamp on the tripod so that the mast can rotate. Figure 12 shows the tripod. Figure 11 shows the mast and D3 antenna in place.

Figure 11

Figure 12

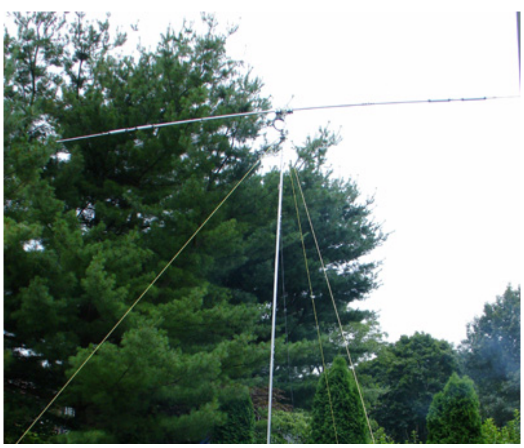


Figure 13

Figure 14

Parts List – Mast

Custom-made - Slip Ring 4" x 4" x 1/8" aluminum, 1-3/8" hole in center, 3/8" holes for rings
(1) McMaster-Carr 9041K12 – 4" x 12" x 1/8" aluminum strip, $8.13

(4) McMaster-Carr 3885T11 - Spring snap rings, 2.5" overall length, $1.60 each

(4) McMaster-Carr 89965K751 - 1.25" OD, 1.37" ID (0.065" wall), aluminum tubing, 6' length, $32.91 each

(1) McMaster-Carr 8982K23 – 1.5" x 1.5" 90 degree angle, 1/8" thick aluminum, 8' length, $22.55

(1) McMaster-Carr 90272A554 - 1/4-20 x 3" zinc plated screws (box of 100), $14.35

(1) McMaster-Carr 98970A129 - 1/4" zinc plated washers (box of 100), $3.11

(1) McMaster-Carr 90480A029 - 1/4-20 zinc plated hex nuts (box of 100), $2.28

(1) McMaster-Carr 90866A029 - 1/4-20 zinc plated wing nuts (box of 100), $8.38

(1) McMaster-Carr 4807K275 – 1-1/2" pipe seal ring, $2.63

(2) McMaster-Carr 60475K82 – 1-1/2" ID, 2.25" OD set screws nylon shaft collar, $10.92 each

200 feet 3827T37 – 1/4" diameter twisted nylon rope, $18.62

(1) On Stage Model SS7761B Reversible 1-1/2" – 1-3/8" Speaker Stand (the tubing must be 1.5" in diameter and removable), $49.95

(5) CampMor 23504 - Heavy Galvanized Steel Hook Stakes - 18 inch, $3.29 each

(1) 3/4" x 4" x 6' wood for the ground to hold the tripod in place.

Silicon grease

Parts List – 1/4 Wave Antenna

2 - 20 meter or other Hamsticks (they must be tuned with an antenna analyzer)

1 – PL259 connector

1 – UHF female to female adapter

2 feet RG8X cable

(2) 3/8" Soldier lugs (ring terminals)
(1) McMaster-Carr 7113K814 - 3/8" hole ring terminals, package of 10, $1.71

21" piece of 1-1/4" ID PVC pipe
(1) McMaster-Carr 43415K35 1.660 OD, 1.278" ID, 1-1/4" PVC pipe, 5' length, $18.44

(2) McMaster-Carr 90264A470– 3/8-24 x 1-3/4" coupling nuts, $0.82 each

(2) McMaster-Carr 90108A417 – 3/8 washers, package of 100, $3.88

(2) McMaster-Carr 91102A760 – 3/8 lock washers, package of 100, $2.11

(2) McMaster-Carr 92620A654 – 3/8-24 x 3/4" hex bolts, package of 25, $4.28

(2) McMaster-Carr 90276A572 - 1/4-20, 4" screws, package of 100, $9.38

(4) McMaster-Carr 98970A129 - 1/4" zinc plated washers (box of 100), $3.11

(2) McMaster-Carr 90866A029 - 1/4-20 zinc plated wing nuts (box of 100), $8.38