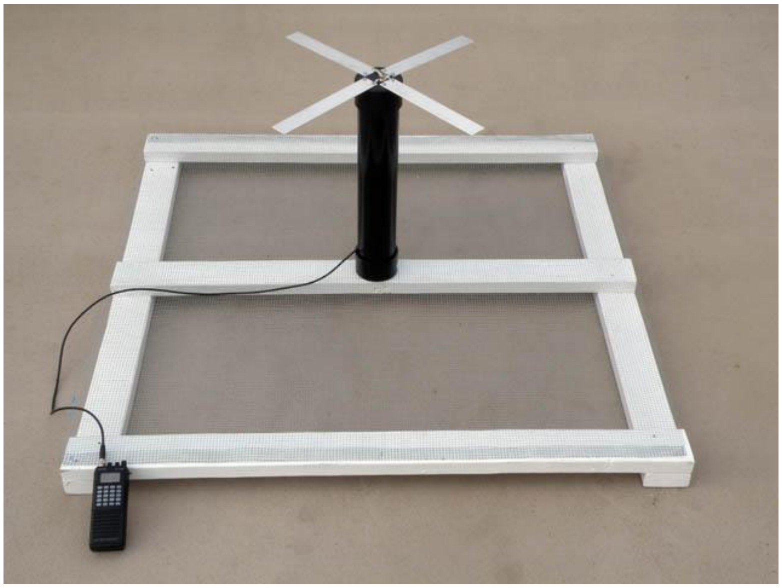
Build this UHF omni Satcom Antenna



Part 1 in this issue: UHF Satcom basics and antenna design criteria. Part 2 in a follow-up issue will focus on construction and using the "MT Omni X-wing".

Snagging military comms is one of my favorite hobbies and nothing peaks my interest more than signals traveling over 23,000 miles from space to reach my antenna. UHF Satcom is a primary mode of communication for US and allied military forces with typical radios having a transmit power around 20w. Some newer handheld transceivers are being pressed into Satcom service with only 5w of transmit power and the antenna is a key part of the system and crucial for reliable communications.

As of this writing, I know of no affordable off the shelf UHF Satcom antennas for the hobby market and checking my favorite auction sites reveal the prices of rare surplus military Satcom antennas are at an all time high. What's a Satcom hungry monitor enthusiast to do? Well, first we need to learn a few things about UHF Satcom reception and see what's required.

Let's take a look at some common antennas used for the military UHF Satcom service. The picture below shows several directional types ranging from a large crossed Yagi for fixed station use to smaller and more portable versions for manpack and hand-held use. There is also a hemispheric omni shown which is used on some vehicles and commo shelters and a vehicular" X-wing" that is of particular interest.

The large crossed Yagi to the far left has considerable gain over most models, which comes in handy when pointing low on the horizon and to better close the satellite link when other stations are using low power or smaller antennas. This particular model is a Dorne & Margolin DM C122 with a maximum gain of 14dBic. The “ic” references to a circular polarized isotropic antenna.

The two antennas to the right and down are fairly common manpack antennas from Dorne & Margolin, model DM C120 and Trivec-Avant, model AV 2040. These are specified at 6 and 7dBic gain respectively and the Trivec-Avant has an optional snap on director element set (not shown) that brings the gain up to 11dBic. Centered between these is a very compact (and covert) cross Yagi from Dorne & Margolin rated at 5dBic gain.

All antennas mentioned so far do a good job of receiving UHF Satcom when mated with a sensitive police scanner or communications receiver that covers 225-400MHz in narrow FM mode. The drawback so far is you may need to point these antennas at multiple satellites depending on your location.

The dome antenna at the right rear is omni directional and intended for vehicles and commo shelters that must remain in contact despite location or motion. The gain is not so impressive at 2dBic but it does have a radiation pattern that covers nearly horizon to horizon with fairly consistent performance.

There are usually tradeoffs in antenna design and this one gives up gain for very wide coverage. This antenna is typically used with a 200w amplifier and receive preamplifier to make up for the low gain.

Finally we get to the magnetic mount X-wing at the right front, which is a recent addition to the military antenna arsenal and primarily used for mobile “satellite on the move” or SOTM. This antenna is rated at 8dBic gain and for an omni that’s quite high.

However, looking at the X-wing with the popular antenna modeling program EZNEC we find most of this gain is pointed straight up in a wide lobe and performance drops off as look angles get below about 30 degrees off the horizon. Otherwise the X-wing works very well and I have used it on the roof of my vehicle while traveling with a hand held scanner listening to Brazilians pirating US satellites. This antenna was an inspiration for our project and we'll come back to it later in this article.

Lets cover some basic antenna requirements for UHF Satcom reception. Frequency range for downlink spans from about 243MHz to 270MHz, that's a fairly broad spectrum but manageable. Next is the polarization, which is Right Hand Circular. With some of the linear polarity designs like a basic Yagi you will loose about 3dB of your receive signal right up front due to polarization mismatch. We should strive for a Right Hand Circular antenna.

Searching the Internet reveals many home brew directional UHF Satcom antennas like Axial Mode Helices, Crossed Yagis and a few omni types like the Quadrifiler Helix and Eggbeater. Building most of these require sharp mechanical skills, scaling dimensions from amateur frequency ranges, finding odd impedance coax for matching or using expensive test equipment to tune various parts of the antenna. I want to keep this project simple for our readers so many of these designs were ruled out. Another hurdle is where to point some of these antennas once they are built and an omni directional like the X-wing is sounding better as we progress.

I find conflicting information on where the US military UHF satellites live but there seems to be four major orbital locations to cover the entire globe. Two closely spaced slots sit over the equator roughly inline with the center of the US at 100° W and 105° W, one centered over the Atlantic Ocean around 22.5° W, one over the Indian Ocean at 72° E and three over the Pacific Ocean at 177° W, 172° W and 172° E. Other countries have fleets of UHF satellites and there are many other orbital locations in use besides what is listed here. For additional information on satellite locations and frequency information you might check this excellent site: www.uhf-satcom.com.

Now, with the 100° W and 105° W orbital slots being roughly in line with the center of the US, the maximum elevation needed anywhere within the continental US (CONUS) would be about 60 degrees off the horizon when viewed from the southern most central point in the US near Brownsville, TX. Most other locations in the US will point at lower elevations, especially when looking at orbital slots over the Atlantic or Pacific Oceans.

This brings us back to the X-wing antenna, which works very well for satellites overhead but starts to loose performance as you get very low on horizon. Lets see if we can make our own version with some improvements tailored for the US, Europe and other regions that share a similar Longitude.

The commercially made X-wing is basically a set of two cross dipoles fed 90 degrees out of phase to create the desired circular polarity. The dipole elements sit approximately 1/4 wavelength above a reflector (vehicle roof, hood, etc.) to achieve the desired pattern, as verified with the popular antenna modeling program EZNEC.

At 1/4 wave above a reflector the dipole impedance is not far from 50-ohms and the wide elements are partially responsible for the broad bandwidth, or the full 225 to 400MHz band for this commercially made antenna. A 50-ohm, 90-degree hybrid divider provides the necessary phase shift between dipoles to create circular polarity and non critical lengths of 50-ohm cables would be used to feed the dipoles

Using EZNEC we find that moving the dipole elements up near 1/2 wavelength produces a null straight up but brings the main lobe down to about 40 degrees off the horizon. This lobe is wide enough to cover a more suitable 20 to 60 degrees off the horizon for use in the Continental US and other regions that share a similar Longitude. We'll use this dipole height for our project antenna.

We also need to house and feed the dipoles properly to create Right Hand Circular Polarity and to match our 50 ohm feedline to the receiver. A commercially made 90-degree hybrid is out of the question for this project and a simple coax Tee with critical lengths of coax will be used to feed the dipoles and create circular polarization. At near 1/2 wavelength above a reflector the dipoles are closer to 75 ohms and would require an odd impedance phasing harness so here is our first compromise. We'll use 75-ohm RG-6 TV coax for the phasing harness.

For the dipole support I chose 3" ABS pipe and caps to allow ample room inside for the phasing harness and connectors. The elements are made from 1 1/2" wide by 1/16" thick aluminum stock, which is readily available at many home improvement centers. These wide elements will provide ample bandwidth.

The antenna needs to sit above an adequate reflector around 48" square (or round) and I used 1/4" mesh galvanized "hardware cloth" stapled to a wooden 2 X 4 frame with an extra center member to affix the ABS pipe support.

So far my prototype antenna is pulling in signals equal to and up to 2dB better (measured on spectrum analyzer) than the commercial X-wing antenna depending on satellite location. That's not bad for a few hours work and less than 1/100 the cost of a commercial version.

I'll cover the detailed assembly instructions and user options in next months issue and here is a parts list so you can start gathering items to build your own MT Omni X-wing antenna. Stay tuned!

Qty	Description	Notes
1	Aluminium flat stock 1 1/2" X 1/16" X 48"	1/8" thick can be used.
1	3" ABS pipe, 24" long	Available in 10ft lengths for around $5.
2	3" ABS pipe cap	Make sure they have a flat top face.
2	Chassis mount female F connector	See note 1 below
1	Type F all female "Tee" adapter	L-Com BA132 or equivalent.
4	Type F male connector for RG-6	Radio Shack 278-223

1	Adapter, type F male to Type N female	SO-239 or BNC to F adapter as option.
1	RG-6 coax, foam type dielectric, 24”	See note 2 below
1	Hardware cloth or chicken wire 48” X 48”	
3	Wooden 2 X 4, 8ft long	
6	8-32 X 1/2” Phillips screws, stainless steel	
6	8-32 hex nuts, stainless steel	
2	Ring lug, 3/8” hole, #12-14 wire	Radio Shack 64-3040
2	Ring lug, #8 hole, #12-14 wire	Radio Shack 64-3117
1	#14 bare copper wire, 6” long	

Note 1
Look for one with a threaded barrel at least 1/2” long. Radio Shack part # 278-0212 is short but will work with a few extra assembly steps.

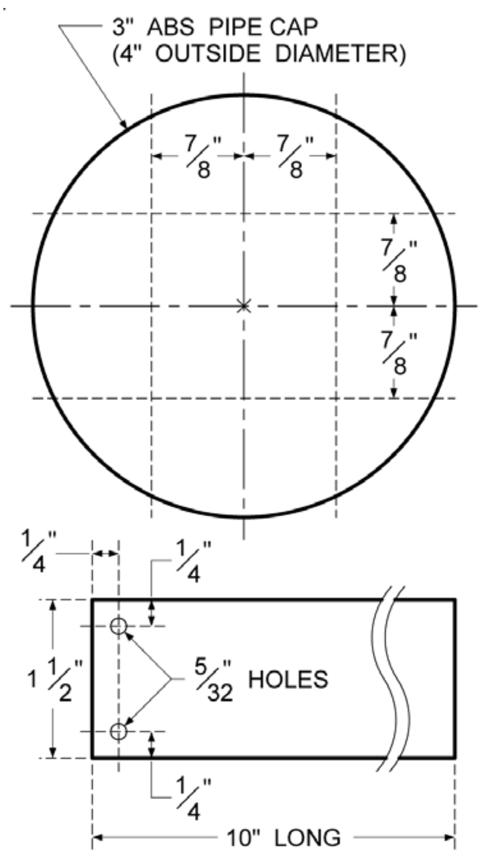
Note 2
If cable specifications are available choose a velocity factor of 80% +/- 2%. I used Carol brand coax from Home Depot.

Build this UHF omni Satcom Antenna: Part 2

In our March issue we discussed some basic criteria for UHF Satcom reception, the ideas that shaped the design of our MT Omni X-wing Antenna and provided a parts list. This issue will focus on assembly of the Satcom Antenna and options for obtaining best reception.

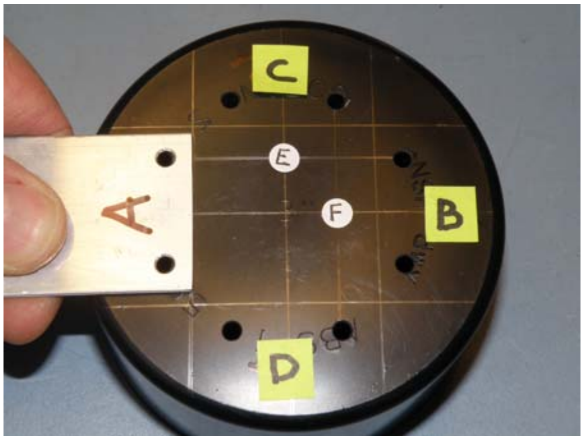
Let's start construction by cutting four lengths of 1 1/2" wide aluminum flat stock to exactly 10" long, being careful to make the ends square. Mark one end of each element with the hole pattern in Figure 1 then drill to 5/32" diameter. I recommend starting all holes with a 1/16" dia drill bit and working up to the final size in increments. Also gently deburr each hole with a countersink or larger drill bit.

Figure 1:



Instead of drawing a complex pattern on the pipe cap for every hole, we'll draw the simple grid shown in Figure 1 and use the elements as a template. A pencil works nicely for marking on the pipe cap. Label the 4 elements with A, B, C and D, which will be needed for reference later on.

Place the drilled edge of each element against the edge of the grid of squares and center the element between the parallel lines extending to the edge of the cap as shown in the picture below. Using the element as a template, mark the location of each set of holes with a pencil. Label each set of hole patterns on the pipe cap with an A, B, C and D to match the element that was used as the template.



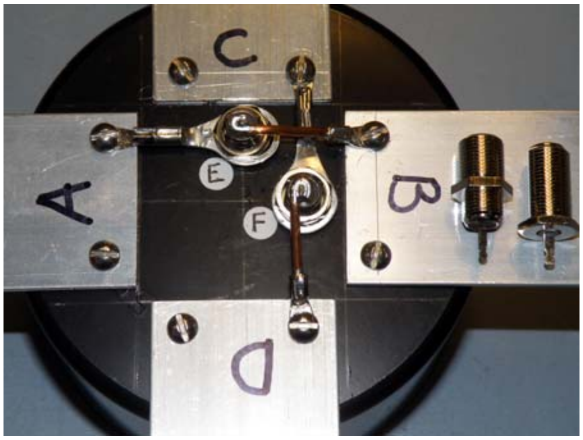
To mark locations for the F type chassis connectors, orient the pipe cap in front of you as shown in the above picture. Using a straight edge, draw a pencil line from the center of the top hole for element A to the center of the top hole for element B. Where this line intersects with the vertical center line is the location of connector hole E.

Using the same technique, draw a vertical line from the center of the right most hole for element C down to the right most hole for element D. Where this line intersects with the horizontal center line is the location of connector hole F.

There are two types of chassis mount F connectors that are suitable for this project, the Radio Shack type shown on the left side of element B in the picture below and the longer barrel type shown to its right. For the Radio Shack connectors drill a 23/64” hole at location E and F, and if using the longer barrel type, drill 3/8” holes.

Temporarily mount the elements using 6-32 hardware placing the screw through the element and pipe cap with nuts on the backside of the cap. There should be enough play in the screw holes so you can line up the opposing elements parallel with each other.

I found the Radio Shack #6 and 3/8” lugs for element ground connections will be at the correct spacing if you remove their plastic insulation and butt them against each other as shown in the picture below. Solder together two sets of these using a short piece of #14 wire between the lugs.



For Radio Shack connectors, gently countersink hole E and F from the inside of the cap to about half the thickness of the cap material. A 1/2” drill bit works ok for this if you take it slow. Do not countersink for the long barrel connectors!

The Radio Shack connectors will be force threaded, female side first into holes E and F from the top side of the cap. Start threading by hand then finish with a wrench or deep socket taking care not to strip the new threads.

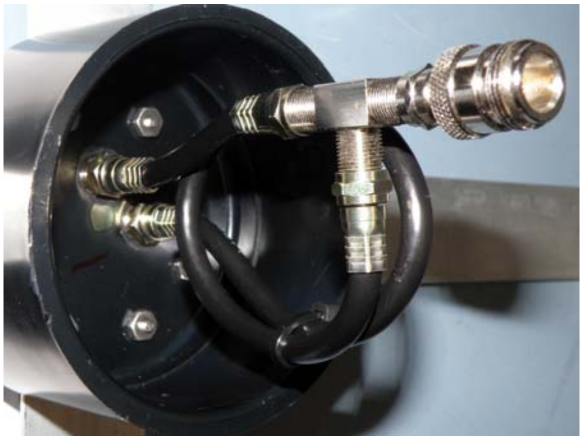
For the long barrel connectors place the 3/8” ground lug assemblies over hole E and F then insert the female side of the connector through the lugs and secure the connectors with nuts from inside the cap. For Radio Shack connectors the lugs will go over the exposed threads on the top of the cap. In either case the ground lug assembly for connector E will attach to element A and connector F to element D as shown in the above picture.

Connect element B and D to the center contacts of connector E and F using a short length of bare #14 wire and #6 lugs as shown in the picture above taking care not to short the wires to the connector ground. Now is the time to make sure all the hardware is tight on the cap assembly.

To make the phasing harness you will cut one length of RG-6 cable to exactly 13 1/2” and another length to exactly 3 1/2”. Using a sharp knife or razor blade, carefully remove 1/2” of outer insulation from each end of both cables being careful not to cut into the braid or foil.

Next measure 1/4” from both ends of each cable and carefully cut through the braid, foil and foam dielectric without nicking the center conductor. Twist and remove the foil/dielectric lumps from both cables leaving 1/4” of exposed center conductor. Carefully install the F connectors on both cables until the dielectric is absolutely flush with the inside bottom face of the connector.

Assemble the two cables on the Tee connector with the longer cable on the center part of the Tee and the shorter cable and F to N adapter (or SO-239, BNC, etc.) on the opposing connectors. The picture below shows the phasing harness attached to the chassis connectors inside the pipe cap. The longer cable goes to connector E and the short cable to connector F. If you get this backwards, the antenna will have Left Hand circular polarization and will not work.



The elements will be spaced 20” above the ground screen using an 18” length of 3” diameter ABS pipe. The ground screen can be wire hardware cloth, chicken wire, a car hood, etc. The screen material should be 48” square or round with gaps no larger than about 1” and it can be stapled to a wooden frame, plywood sheet, or simply set on the ground. The lower pipe cap will screw to your wooden frame or a separate piece of flat wood for support.

If there is clearance below your ground screen you can bring the coax feedline through a hole in the bottom pipe cap as in the picture below, or exit through a hole in the lower side of the ABS support pipe as shown in part 1 of this article. Either way you should consider a drain hole for accumulated water.

Place your new antenna on a flat level surface. Connect antenna to receiver using the shortest practical length of low loss feedline. For feeding long cables there is plenty of room inside the support pipe for a dedicated UHF preamp or a remote TV antenna preamp.

US listeners will want a clear view of the southern sky to the west horizon for west coast use and east coast listeners to the east horizon. For users just north of the equator like Hawaii, tilt the south facing side of the antenna and ground screen upwards to improve reception. Listeners just south of the equator should tilt the north facing side up. Users in Alaska might tilt the north facing side up to improve reception.

We hope you enjoy building and using your new MT Omni X-Wing antenna and snag some rare Satcom traffic. Until next time, stay tuned!