GPS Creations

Application Notes

Construction Details for a GPS Helix Antenna

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The GPS Patch antenna design published in the Oct, 1995 issue of QST magazine, and also placed on the Internet, has the advantages of being cheap, compact, and easy to build. Its main limitation is that it does not track satellites very well at low angles near the horizon. The GPS SPS (Standard Positioning Service) specification calls for tracking down to 5 degrees above the horizon, which cannot be met with a patch antenna design. After building and testing several patch antennas, I decided to try to design something better.

GPS satellites transmit a signal that is Right-Handed Circularly Polarized (RHCP). A review of common antenna designs contained in the American Radio Relay League (ARRL) Antenna Book (17th Edition, 1994) led to the conclusion that a RHCP Helix antenna (See Section 19, page 22- 26) would provide better performance. After building several prototypes, this has proven to be correct.

The remainder of this document contains details for building such an antenna, and various things that I learned in the school of hard knocks along the way.
Although not as compact as a patch antenna, this design still retains the desirable attributes of cheap and easy to build. Due to the very high microwave frequency used by the GPS system, the wavelength is quite short, so the antenna is still reasonably compact.

A Little Background Information

Given:

1. GPS SPS L1 band frequency is 1575.42 Mhz, or 1575420000 Hz.
2. The "official" GPS speed of light is 299792458 M/Sec.

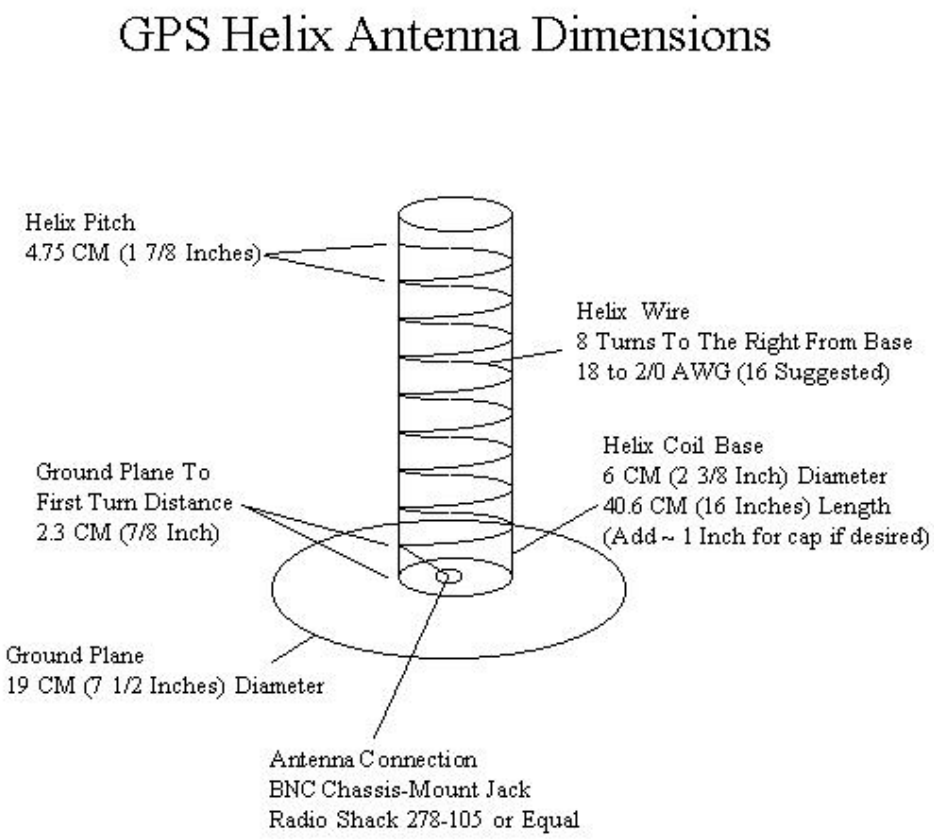
Therefore:

The wavelength a GPS antenna must be designed for at 1575.42 Mhz is:
299792458 / 1575420000 = .19029 Meters, or ~ 19 CM. or ~ 7 1/2 Inches.

To put it mildly, at microwave frequencies antenna design is fraught with both peril and magic. The ARRL Antenna Book gives some range in most of the Helix antenna dimensions, but these are intended for much lower frequencies (and longer wavelengths) used by Ham radio operators. I can state from experience that variations on the design shown may provide absolutely zero results. If you wish to get creative, try what is specified first for use as a reference point.

The antenna described in this document works surprisingly well, given that it is not amplified or otherwise optimized in any way other than being cut to the exact frequency of GPS signals. Using two different Garmin GPS-45 receivers, it is routinely capable of locking on to 7 or 8 satellites, when a patch antenna could do no better than 3 to 5.

What Does It Look Like?



Bill Of Materials

Ground Plane -
Any commonly available sheet metal may be used. I have tried aluminum, brass, and stainless steel with equal results. The thin aluminum sheet typically available from hardware store and building supply sources works well, although it is very thin and may cause some problems with mounting, as discussed later.

Helix Coil Base -
In an unusual coincidence of project requirements and commercially available materials, plain old 2 Inch diameter white PVC pipe has a circumference of 19 Centimeters, which is for all practical purposes an exact match of the GPS wavelength. Two inch gray plastic electrical conduit also has these same dimensions. It costs a little more, but looks a little nicer in the finished antenna unless you have a white vehicle.

Helix Wire -
A wide range of wire diameters may be used. Ordinary American Wire Gauge (AWG) 16 gauge copper wire was used in most of the prototypes and works fine.

Antenna Connector -
Any commonly available RG58, RG8X, or lower loss coaxial cable connector may be used if you want to be able to disconnect the antenna cable. Direct soldered connection of the cable to the antenna should also work satisfactorily.

Construction Details

1. Start with the ground plane.
   Cut a 19 CM (7 1/2 Inch) diameter circle out of whatever sheet metal you decide to use. Drill a hole in the center to accommodate the coax connector, or grommet / strain-relief if you plan to solder the coax directly to the helix wire and ground plane. Be aware that aluminum and stainless are very hard to solder, and that brass or copper are best for this approach. Mount the coax connector or other attachment device at this time. If you use aluminum and the Radio Shack coax connector shown in the diagram, the only soldering required is to the center pin of the connector. The ground plane connection is made through the shell of the connector by mechanical connection.

2. Cut the Helix Coil Base.
   Cut a 40.6 CM (16 Inch) length of any non-metallic material for the base. If you want to glue a standard pipe cap on the outer end to keep moisture out, add about 1 inch to this length. Suggested material is 2 Inch diameter plastic water or electrical conduit pipe, which has an outside circumference of 19 Centimeters, for an exact match of the GPS L1 wavelength. Be sure to obtain a square cut so that the base will be perpendicular to the ground plane after it is mounted.

3. Layout the Helix Coil Base.
   Clamp a ruler to the Helix Coil Base and draw a line from one end to the other, parallel to the center line of the cylinder. Along this line, measure 2.3 Centimeters (7/8 Inch) from one end (to be the base) and place a mark for the beginning of the first turn of the Helix winding. From this first mark, and along the end-to-end line you drew first, measure and mark 8 points that are 4.75 Centimeters (1 7/8 Inches) apart.

4. Drill the Helix Coil Base.
   Use a 1/16 Inch bit (assuming 16 gauge insulated wire is used) to drill a hole at the last mark nearest each end of the Helix Coil Base.

5. Decide how to mount the Helix Coil Base to the Ground Plane.
   If you plan to use glue, no action is required here- just don't use hot melt glue or the antenna will fall apart when exposed to the sun. A sturdier approach is to use number 4-40 machine screws. Lay out 3 marks on the base end of the Helix Coil (see number 3 above to identify the base end) spaced 120 degrees apart. Use a number 43 bit (or 5/64 fractional bit) to drill into the pipe base at each of the marks. Follow this with a number 4-40 tap to cut threads into each hole. Screw 4-40 machine screws into each hole. Center the Helix Coil Base on the Ground Plane, and tap it with a hammer to make a dimple where each of the 3

machine screws contact the ground plane. Drill each of the marks with a clearance hole size for the 4-40 machine screws.

6. Connect the Helix Wire to the antenna connection.
   If you are using the suggested coax connector, just solder the end of the wire to the center of the connector. Pass the free end of the wire from the inside, through the hole located 7/8 Inch from the base end of the Helix Coil Base. If you are using another type of connection, connect the center of the coax cable to the Helix Wire, and the coax shield to the ground plane.

7. Attach the Ground Plane to the Helix Coil Base.
   Use the 3 number 4-40 machine screws or glue, as desired.

8. Wind the Helix Wire.
   Pull the Helix Wire tight where it passes through the Helix Coil Base. Wind it to the right around the Helix Coil Base smoothly and evenly. As you complete each turn, make sure that the wire passes over each 1 7/8 Inch reference mark you made back in step 3. Continue winding to the top, and pass the wire through the top hole drilled earlier. Pull the wire tight through the hole, and bend up toward the top of the pipe. Cut the wire off about 1/4 Inch from where it makes the turn inside the pipe so it will remain in place. Adjust the windings so they are evenly spaced, and apply glue as needed to keep them from moving.

9. Connect the antenna to a GPS receiver.
   Test for proper operation.

10. Glue the cap in place.
    (At the top of the antenna if you cut the Helix Coil Base long enough to allow for this). Attach the antenna to whatever base you plan to use. See below for more information about variations in the design for different mounting configurations.

Mounting Considerations

There are many different ways to mount the antenna. The main considerations are that the mount be able to withstand the expected wind loading, and that it remain vertical. For automotive use, you should plan for 110 MPH winds (70 MPH into a 40 MPH head wind).

1. Ground plane mount.
This mount is suggested only if you used a heavy enough gauge sheet metal for the ground plane- the thin hardware store variety aluminum will buckle and throw the antenna off its vertical axis. Extend the three 120 degree radials for the number 4-40 machine screws out to the edge of the ground plane. Drill a ¼ inch hole near the edge of the ground plane on each of these lines. Select an appropriate base, and mark the location of these holes on it. Drill and tap each mark for a 1/4-20 inch bolt, and use this size 1 1/2 Inch nylon bolts and nuts to attach the antenna to the base. Do not use metallic bolts,

since this will alter the electrical characteristics of the ground plane. Glue 4 large permanent magnets to the bottom of the base and cover them with thin rubber to prevent scratching of the vehicle's paint.

2. Pipe Mount.
Instead of cutting the Helix Coil Base to 16 Inches, make it longer as needed to make a pipe-type mount. Cut the center hole of the ground plane out to the diameter of the pipe, and attach the ground plane with glue, plastic collars, or some other non-conductive means. You will have to drill an extra hole and solder the coax cable shield to the ground plane with this approach, so brass or copper for the ground plane are suggested.

Impedance Matching

The calculated impedance for a Helix antenna at this frequency is 26.6 Ohms, which is not a very good match for 50 Ohm RG-58 coax cable. In spite of this mismatch, the antenna works so well that I have not attempted to design an impedance matching circuit. If anyone more knowledgeable about designing such circuits at these frequencies would like to do so, I would appreciate knowing what they come up with.