

ADS-B Antenna

Build this 8.6 dBi 1090MHz Vertical Dipole Array for \$20

Automatic Dependent Surveillance-Broadcast, or ADS-B, is a surveillance technology in which an aircraft determines its position via satellite navigation or other sensors and broadcasts it, enabling it to be tracked. There are several smartphone apps available that allow users to monitor aircraft positions, flight numbers, speed, altitude and several more parameters. A receiving system can be built with a Raspberry Pi, a receiver dongle, and an antenna. This article is based on using the Flightradar24 and FlightAware apps.

Vertical Dipole Arrays

My first antenna was a magnetic base $\frac{1}{2}$ wavelength vertical whip. It worked and allowed me to get my system running. I then decided to try to improve the antenna and built a J-Pole base on an old L.B. Cebik design. The result was a bit disappointing, so I decided to try scaling my Vertical Dipole Array design (www.kg4jih.com/vda.html) from 2m (146 MHz) to 1090 MHz. I saw an immediate doubling of the number of aircraft received.

Living in an HOA restricted neighborhood, I am forced to place my antennas in the attic. This attenuates all RF signals. I try to compensate for this loss by building the highest gain antennas that will fit in the attic space.

Construction

Drawing Sheet 1 presents an overview of the 4-element vertical dipole array assembly. Cut the 8 dipole elements from 14 AWG solid wire. I am a stickler for accuracy, so I ground the wire lengths to size using a circular sander. Measure and mark the poplar board according to the drawing. Place a length of tape along the entire $\frac{1}{4}$ " edge of the board. Tin one of each copper wire element with solder. Place each dipole element (with the tinned end of the elements facing each other) against the tape and affix the elements with clear Gorilla glue and allow to dry. The 8-element array was built using 3 sheets of $\frac{1}{4}$ " x 6" x 36" poplar to get a panel 77" long. The third sheet was cut to extend the length from 72" to 77" and to make splice panels which were glued to the bottom of the panel.

Phasing Harness

The phasing harness is based on feeding four 50 Ω antennas from one 50 Ω feedline. When cutting cable lengths, remember that the velocity factor applies only to that portion of coax where the center conductor insulation is still in place. The math involved for calculating coax impedance and length is as follows:

Lambda (λ) is the physical wavelength of coax and is defined as:

$$\lambda = (\text{Electrical Wavelength at } F_0) \times (\text{Velocity Factor of the Coax})$$

$$\text{Equation 1: } \frac{1}{4}\lambda = (2952/F_0) \times (VF)$$

Where:

$$\frac{1}{4}WL = 2952/F_0 \times VF$$

$$F_0 = 1090 \text{ MHz}$$

$$VF = 0.82$$

$$\frac{1}{4}WL = 2952/1090 \times 0.82$$

$$\frac{1}{4}WL = 2.2208" = 2.25"$$

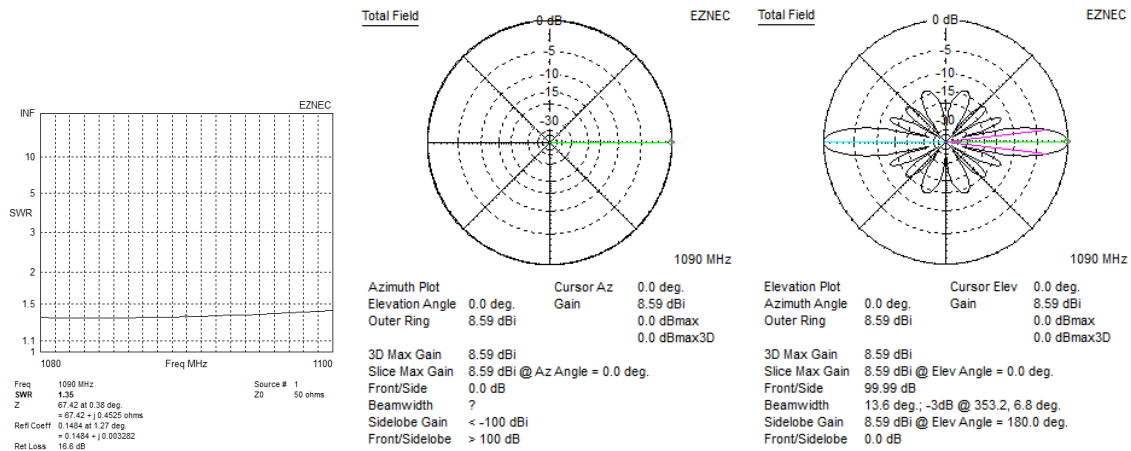
- 1 x 1/4WL=2.25"
- 3 x 1/4WL=6.75"
- 5 x 1/4WL=11.25"
- 7 x 1/4WL=15.75"
- 9 x 1/4WL=20.25"
- 11x 1/4WL=24.75"

Cut the mini 75Ω coax to the lengths shown on the drawing. Remove the aluminum foil near the braided shield. Solder each coax length to the elements and hot glue the coax to the board near the solder joints. Solder the coax center to the upper dipole wire and the coax shield to the lower dipole wire for all four dipoles. Using an ohmmeter, verify that all upper dipole elements are connected to the SMA connector center pin. Next, verify all lower dipole elements are connected to the SMA connector shell. Also, verify that there are no short circuits between the SMA connector center and shell.

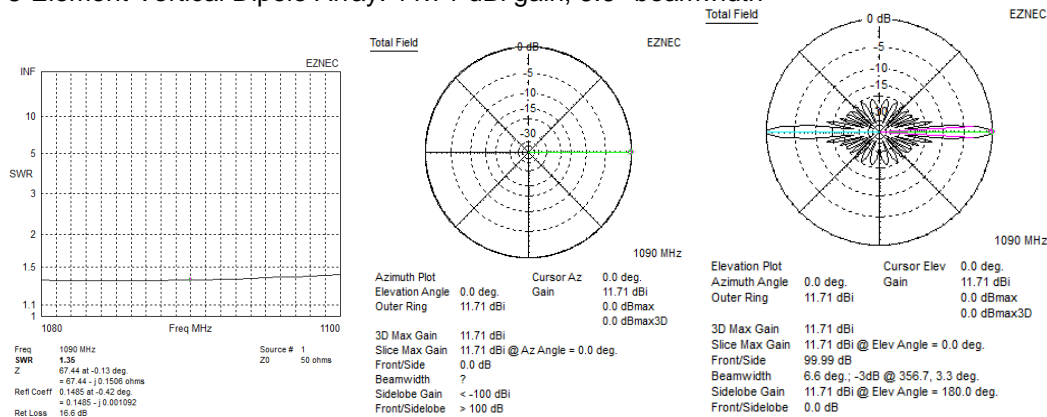
The antenna is not weatherproof, so it was mounted in the attic. Drawing sheet 2 illustrates an idea of enclosing the elements and coax inside PVC pipe. Replace the SMA connector with any length of 50Ω coax to the N connector.

Antenna EZNEC Models

4-Element Vertical Dipole Array: 8.59 dBi gain, 13.6° beamwidth



8-Element Vertical Dipole Array: 11.71 dBi gain, 6.6° beamwidth




SWR Measurement

A newly purchased MiniVNA showed the 4-Element Vertical Dipole Array SWR to be 1.14:1 at 1090 MHz. The 8-Element Vertical Dipole Array measured 1.09:1.

Aircraft Tracked

Flightradar24 display using a vertical whip antenna. Aircraft detection range is approximately 50 miles.



The screenshot shows a mobile browser interface with the following elements:

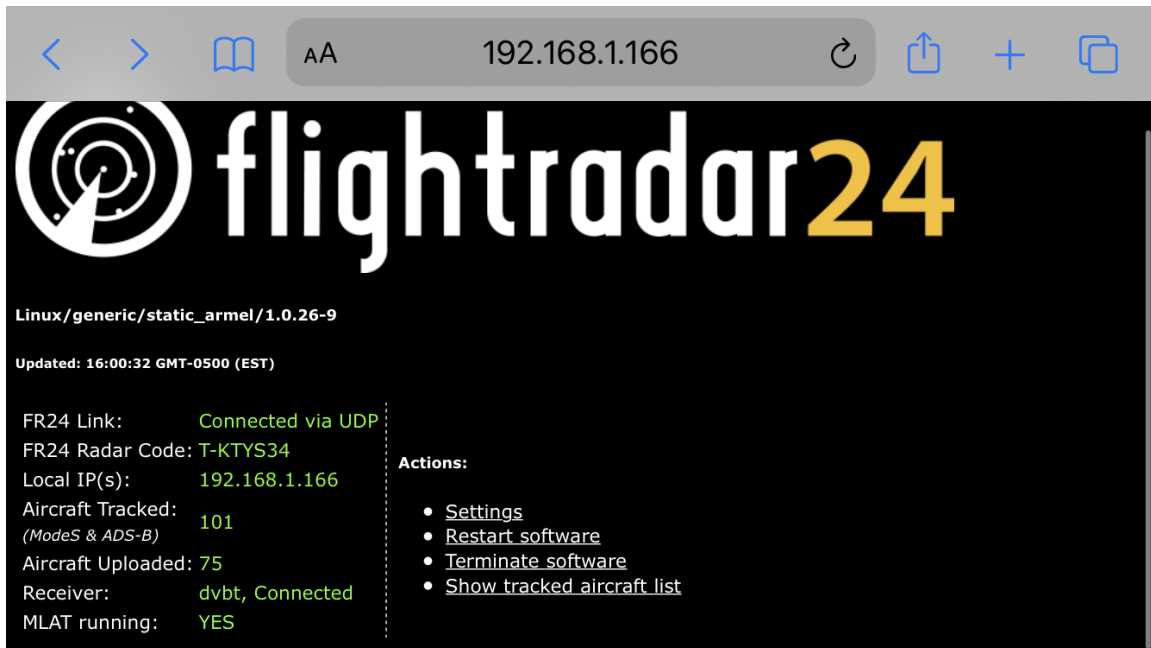
- Top Bar:** AT&T carrier, 5:11 PM, 31% battery.
- Address Bar:** AA 192.168.1.166 with refresh and download icons.
- Header:** Flightradar24 logo.
- System Info:** Linux/generic/static_armel/1.0.26-9, Updated: 13:55:16 GMT-0500 (EST).
- Status:** FR24 Link: Connected via UDP; FR24 Radar Code: T-KTYS34; Local IP(s): 192.168.1.166; Aircraft Tracked: 37 (Modes & ADS-B); Aircraft Uploaded: 31; Receiver: dvbt, Connected; MLAT running: YES.
- Actions:** Settings, Restart software, Terminate software, Show tracked aircraft list.
- Bottom Bar:** Navigation icons for back, forward, share, bookmarks, and tabs.

Flightradar24 display using the 4-Element Vertical Dipole Array. Aircraft detection range is approximately 100 miles.



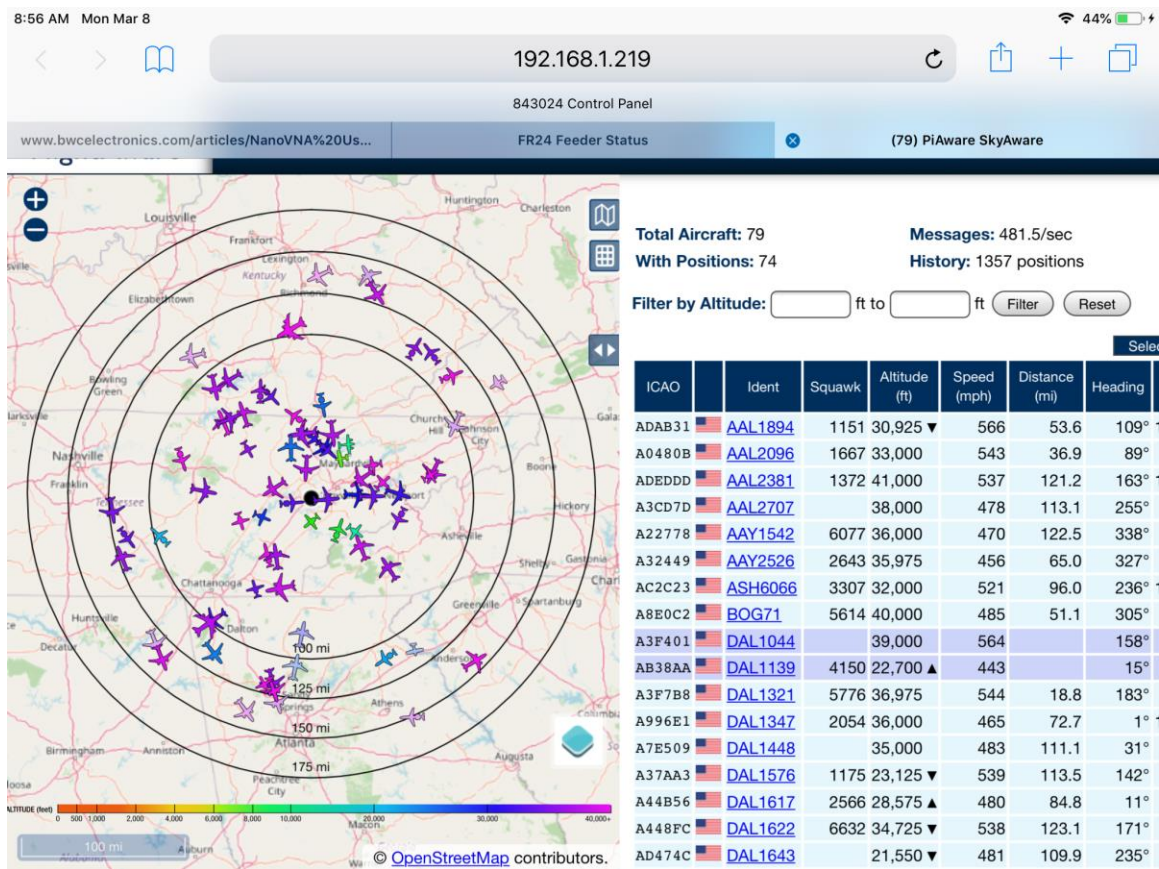
The screenshot shows the Flightradar24 web interface. At the top left is the logo, a white radar icon with a white arrow pointing towards the center. To the right of the logo, the text "flightradar24" is displayed in a white sans-serif font, with "24" in a larger, yellow font. Below the logo and title, the text "Linux/generic/static_armel/1.0.26-9" is shown. Underneath that, "Updated: 17:14:53 GMT-0500 (EST)" is displayed. The main content area is divided into two columns. The left column contains the following status information: "FR24 Link: Connected via UDP", "FR24 Radar Code: T-KTYS34", "Local IP(s): 192.168.1.166", "Aircraft Tracked: 86 (Modes & ADS-B)", "Aircraft Uploaded: 69", "Receiver: dvbt, Connected", and "MLAT running: YES". The right column is titled "Actions:" and contains a list of four items: "Settings", "Restart software", "Terminate software", and "Show tracked aircraft list".

Preliminary data shows the 8-Element Vertical Dipole Array has expanded my aircraft detection range to 130 miles.



The screenshot shows the Flightradar24 web interface, similar to the previous one but with updated data. At the top, a browser address bar shows the URL "192.168.1.166". Below the browser bar, the Flightradar24 logo and title are visible. The text "Linux/generic/static_armel/1.0.26-9" is shown. Underneath that, "Updated: 16:00:32 GMT-0500 (EST)" is displayed. The main content area is divided into two columns. The left column contains the following status information: "FR24 Link: Connected via UDP", "FR24 Radar Code: T-KTYS34", "Local IP(s): 192.168.1.166", "Aircraft Tracked: 101 (Modes & ADS-B)", "Aircraft Uploaded: 75", "Receiver: dvbt, Connected", and "MLAT running: YES". The right column is titled "Actions:" and contains a list of four items: "Settings", "Restart software", "Terminate software", and "Show tracked aircraft list".

Attempts to get Dump1090 working for Flightradar24 were unsuccessful, so I built a new station and loaded FlightAware. This gave me the ability to view aircraft positions on a map with distance rings. The FlightAware station is using the 8-Element Vertical Dipole Array and, so far, tracks aircraft up to 165 miles. Also, this station has a much higher percentage of tracking aircraft with positions vs total aircraft detected (95% vs 75%).



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