Virtual Radar from a Digital TV Dongle

Track aircraft by reprogramming an inexpensive digital TV USB stick to receive Automatic Dependent Surveillance-Broadcast signals.

Robert Nickels, W9RAN

It is now possible to track aircraft within a 100 mile radius and plot their positions on a real-time display — for about $25! There is a caveat, however — the tracked aircraft must employ a special ADS-B transmitter that continually transmits the aircraft's flight parameters. The majority of all aircraft flying in US airspace will not be required to use this system until 2020. So, while you probably can't track that Piper Cub buzzing your neighborhood on a Sunday afternoon, there is still plenty of fun to be had, and you won't even need to heat up your soldering iron. All you need to do is obtain an inexpensive DVB-T stick that plugs into a computer's USB connector (this type of device is often referred to as a *dongle*), download some free software, and build a simple antenna.

ADS-B

Automatic Dependent Surveillance-Broadcast, or ADS-B, is a replacement for (or supplement to) traditional aircraft position detection by ground-based radar that has been used for more than 50 years for air traffic control.[1] This represents a major change in surveillance philosophy — instead of using radar to interrogate an aircraft and determine its position, each aircraft will find its own position using GPS and then automatically transmit this and other information to a network of ground stations. This change is a key part of the FAA's *NextGen* — the Next Generation Air Transportation System, which is scheduled to be in full operation by 2020.

More than 27 countries are in the process of building ADS-B ground stations and equipping aircraft with the technology, so the number of aircraft that will show up on virtual radar screens will continue to grow in the coming years. ADS-B has the benefit of being less costly to build and operate than ground radar. It also provides better positional accuracy, which will improve safety, particularly at busy airports.

[1]Notes appear on page 42.

Virtual Radar System

My ADS-B receiving system consists of the three major elements shown in Figure 1: a homebrew collinear antenna, a DVB-T TV tuner dongle, and a *Windows*-based PC running *ADSB#* and *Virtual Radar Server* software. While the FAA is putting millions of dollars into its ground station network, you can make yours for about $25.

Antenna

ADS-B signals are transmitted at 1090 MHz. My antenna is a collinear vertical comprised of eight half-wave coaxial offset sections with a half-wave whip at the top.[2] The antenna is omnidirectional and has a gain of 6 dBi. It is designed to be assembled without the need for soldering.

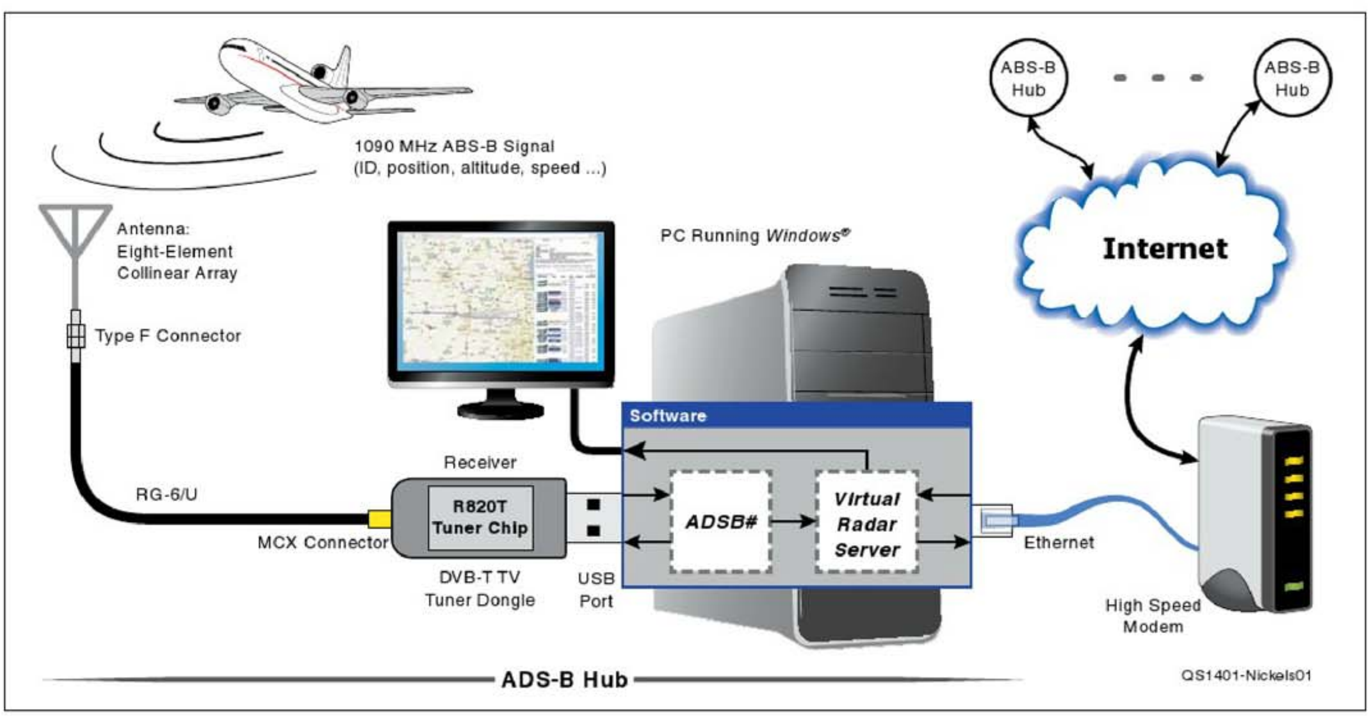


Figure 1 — ADS-B receiving station block diagram.

Receiver

In the US and most of North America, television broadcast stations have switched to digital using the ASTC standard, but in Europe, Australia, and parts of Africa, a different standard called DVB-T (Digital Video Broadcast-Terrestrial) is used. In these areas a small DVB-T stick or dongle is used to receive terrestrial TV broadcasts on laptops and computers.

While the DVB-T stick was intended as a TV receiver, some clever software developers working on mobile communications in a group called Osmocom discovered that this inexpensive hardware could be repurposed for use as a VHF-UHF software defined radio (SDR) receiver. SDR applications soon added support for this new RF front end, which typically tunes as low as 24 MHz, to well over 1700 MHz.[3] It is important to use a DVB-T TV tuner dongle that uses the sensitive Rafael Micro R820T tuner chip. Sensitivity is as good as most communications gear and continuously variable filter selectivity is made possible through DSP. Integrating these elements creates a low-cost ADS-B ground station that rivals the performance of units costing $500 and up.

Software

Conversion from RF to digital is done with an open source application called *ADSB#* (read as "ADSB sharp") created by Youssef Touill and the SDR# development team.[4, 5] This *Windows* application automatically sets the receiver for optimal performance and processes data transmissions from aircraft within range and sends the raw ADS-B data to the real-time display program.

Real-time display (see Figure 2) and data sharing is accomplished with the *Virtual Radar Server* (*VRS*) application.[6] *VRS* decodes the ADS-B information and presents it along with other useful data on a real-time Google Maps display. Data from *ADSB#* is sent using Ethernet protocols so it is not necessary for *VRS* to be running on the same computer as *ADSB#*. *Virtual Radar Server* is a free, open-source development from Andrew Whewell in the UK and provides a great deal of flexibility to present information of interest. *VRS* and *ADSB#* include features for sharing data with other "hubs" that aggregate information in order to to provide a global view of aircraft traffic.

Figure 2 — Real time aircraft tracking using *Virtual Radar Server* software with aircraft positions plotted on Google Maps.

Construction

Parts List

- A DVB-T dongle capable of 1090 MHz reception. Many online sellers exist, just search for "R820T" and "RTL2832" to be sure you get the right kind. Selling prices have dropped below $15, depending on whether you choose a US or China-based seller.
- The DVB-T dongles now use MCX connectors, so you'll need either an adapter or to cut the supplied antenna cable and splice on a new antenna connector of your choice.
- RG-6/U coaxial cable — enough to reach from your PC to the antenna mounting location, plus an extra 5 feet.
- Three Type F male connectors for RG-6/U.
- One Type F type 90° elbow adapter.
- A 5 foot length of ¾ inch PVC pipe.
- One ¾ inch PVC pipe cap.
- One ¾ PVC pipe T.
- One ¾ inch PVC pipe plug.
- Tools — tape measure, electrical tape, utility knife, and a hacksaw.

Coaxial Collinear Antenna

This antenna provides enough gain to hear plane transmissions from 100 miles or more away, yet costs only a few dollars and takes less than an hour to make using the following procedure:

Cut seven pieces of RG-6/U coax 7 inches long, and one piece 10 inches long. Then, expose 1 inch of the center conductor from one end of all eight coax pieces by rolling the coax against the blade of a sharp utility knife to cut through the vinyl outer jacket, foil shield, and foam insulation. Take care not to press hard enough to cut or nick the center conductor. Make sure the end is clear of stray shield wires or foil.

Expose 1½ inches of center conductor from the other end of each of the seven short pieces. You should end up with seven

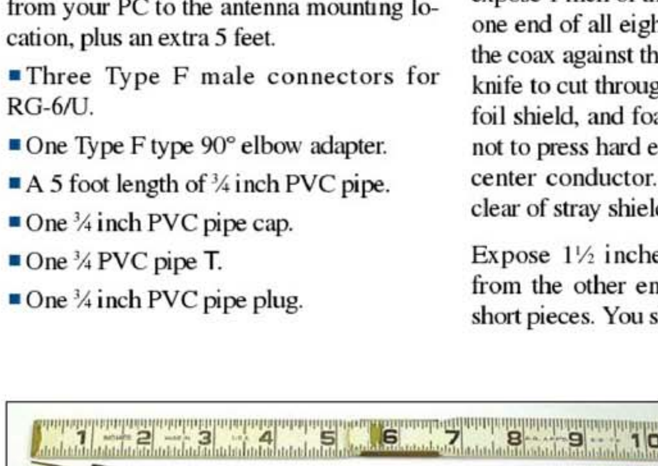


Figure 3 — Collinear antenna sections cut from RG-6/U coax. The different lengths of exposed center conductor at each end aid assembly.

Figure 4 — Assembly is eased by heating the outer jacket either in an oven or with a heat gun. Pinch the outer covering to create a small gap and then first insert the longer exposed conductor between the outer jacket and the foil shield. Next insert the shorter exposed conductor and slide the two pieces together using an alternating twisting motion.

Figure 7 — Top section of the antenna with the 4½ inch exposed center conductor acting as a vertical element.

Figure 5 — Continue twisting the two pieces together, keeping the two center conductors parallel.

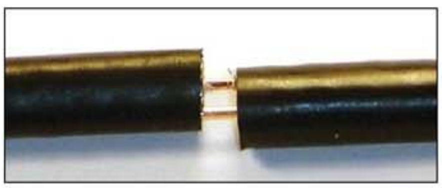


Figure 6 — The final joint with gap of about ⅛ inch. Take care to clear away any wire strands or bits of foil from the center conductors.

pieces of RG-6/U with 1 inch of the center conductor protruding from one end, and 1½ inches from the other (see Figure 3). Inspect the cut ends and use the tip of the knife blade to clear any strands of wire or foil shield from the insulation around the center conductor. Expose 4½ inches of the center conductor from the other end of the 10 inch piece — this will act as a vertical whip at the top of the antenna.

It will be easier to assemble the antenna if the vinyl jackets are made more pliable by heating them. Place the eight pieces on a tray in your oven at its lowest setting (150° F maximum) for 10 to 15 minutes. [Alternatively, use a heat gun or hair dryer to soften the outer coax covering. — *Ed.*]

The collinear elements are assembled by inserting the exposed center conductor from one piece between the outer jacket and aluminum foil of the next piece, in an offset chain as shown in Figure 4. Pinch the outer jacket with your fingers to create a small gap, and then insert the longer wire between the jacket and foil using a gentle pushing and twisting motion. Do the same with the shorter conductor (see Figure 5) and continue to gently twist and push the two pieces together until a gap of about ⅛ inch remains (see Figure 6).

Continue to connect all eight coax sections together in the same way with the 4½ inch wire on top (see Figure 7). Use an ohmmeter to verify that there are no shorts between the foil and inner conductor. A schematic of the completed antenna is shown in Figure 8.

Cut 3 inch pieces of electrical tape and wrap each joint to hold the elements in position and provide protection against the elements. Heat shrink tubing of the right size would work nicely as well. [A dab of silicone sealant at each joint before taping or heat shrinking might be a good idea. — *Ed.*]

Attach a Type F male connector to the bottom of the antenna. The electrical assembly of the antenna is done!

The collinear elements are mounted inside a length of PVC pipe for additional weather protection and to provide for mounting. Feel free to incorporate your own ideas, but the simplest method I've found is use a right-angle Type F adapter (available at most home improvement stores) and a few PVC pipe fittings as shown in Figure 9.

Cut a piece of ¾ inch PVC 42 inches and slide the antenna inside with the right-angle adapter attached to the Type F connector at the base. Drill a hole large enough to pass the feed line coax in a ¾ inch plug and feed the coax through the plug and middle of the T as shown. Add a Type F connector to the end of the feed line, and fit the pieces together as shown. Finish weatherproofing the housing by placing a ¾ inch PVC cap on top. The PVC pipe can be pressed together very tightly, so gluing should not be necessary. This makes it easy to disassemble the antenna if needed in the future. Add a dab of silicone to seal the hole where the feed line goes through the plug.

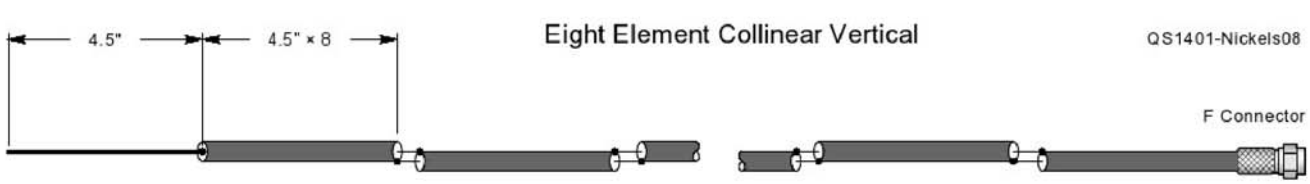
Just Add Software

All that's left is to install two free software programs: *ADSB#* and *Virtual Radar Server*. *ADSB#* is a server that manages the dongle, extracts raw data frames and then transfers them via Ethernet protocol to *Virtual Radar Server* for further processing, and the visual tracking map and user interface.

ADSB#

Download *ADSB#* by running the auto-

Figure 8 — Schematic of the eight-element collinear 1090 MHz vertical antenna. The antenna is comprised of eight half-wave offset sections, each 4½ inches long, and a 4½ inch whip section at the top with a Type F connector at the bottom.



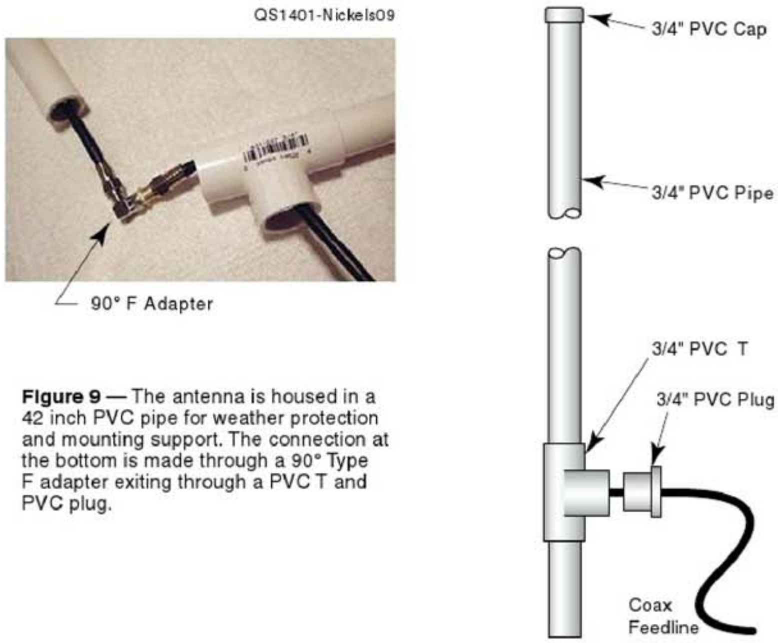


Figure 9 — The antenna is housed in a 42 inch PVC pipe for weather protection and mounting support. The connection at the bottom is made through a 90° Type F adapter exiting through a PVC T and PVC plug.

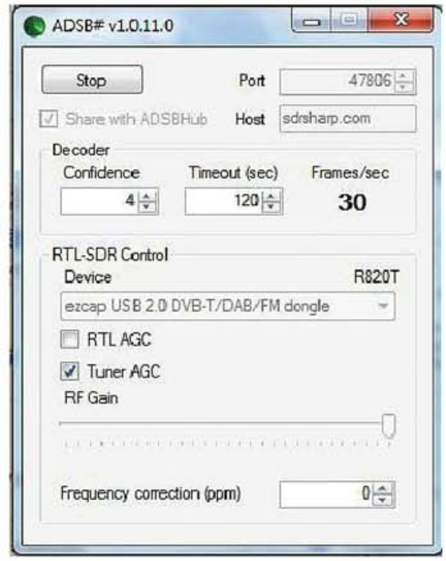


Figure 10 — The *ADSB#* (pronounced "ADSB sharp") control panel.

mated script from: **http://sdrsharp.com/downloads/adsb-install.zip**.

Run the script and open the ADSB folder that it creates. A program called *Zadig* must be run one time to install the *WinUSB* driver before the dongle can be used.[7] Launch *Zadig*, then click OPTIONS and LIST ALL DEVICES. The DVB-T dongle will show up as BULK IN 0 — select it, make sure WINUSB is the selected choice, and click INSTALL DRIVER. That's all there is to it!

Note: *Zadig* must be run with administrator privileges, and some anti-malware programs may try to prevent it from installing the needed driver. For more help with *Zadig* issues see **https://github.com/pbatard/libwdi/wiki/zadig**.

To launch *ADSB#*, leave all settings at their default values and click the START button. The FRAMES/SEC indicator will give an indication of how many ADS-B signals are being received (see Figure 10).

Virtual Radar Server

Virtual Radar Server is an open source *.NET* application that runs a local web server. You can connect to the web server with any modern browser and see the positions of aircraft via Google Maps, generate reports, and integrate other useful information. Your PC must be running *Windows XP SP2* (or newer), either 32-bit or 64-bit, along with *Microsoft .NET Framework 3.5.5*, which can be obtained from the Microsoft Download Center if necessary.

Download *VRS* from the following URL and follow the installation guidelines: **www.virtualradarserver.com/download.aspx**.

The first time *Virtual Radar Server* runs it will prompt you for some user configuration information (see Figure 11). The configuration can also be changed at will by using TOOLS-OPTIONS. Configure the following fields as shown:

1. DATA FEED

1.1 DATA SOURCE: AVR OR BEAST RAW FEED

1.2 CONNECTION TYPE: NETWORK

2. NETWORK

2.1 ADDRESS 127.0.0.1

2.2 PORT 47806

VRS communicates by way of a built-in web server and the above settings tell it to look to port 47806 of your computer (127.0.0.1 is the "local host" or the local Ethernet interface) for the raw ADS-B data stream that is being generated by *ADSB#*. Click TEST CONNECTION and confirm that a connection can be made.

Return to the main screen and note the URL adjacent to SHOW LOCAL ADDRESS — click this link and your browser will

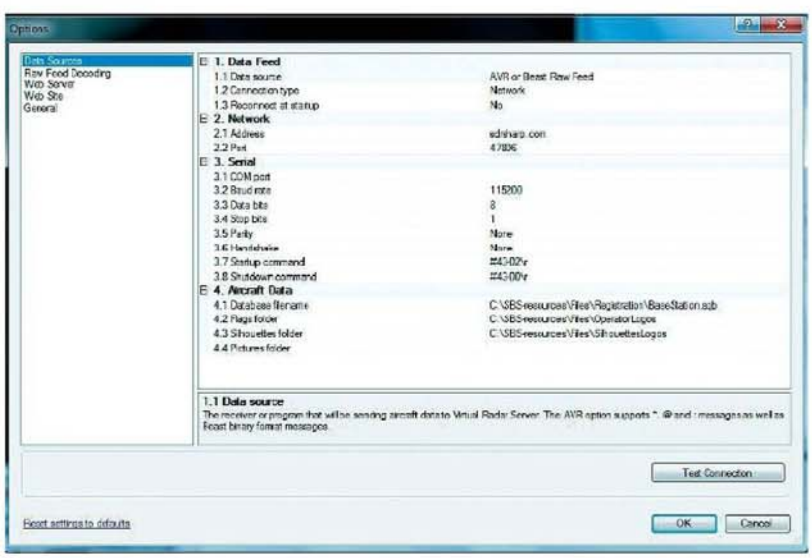


Figure 11 — The *Virtual Radar Server* control panel.

display a map generated by Google Maps and information about ADS-B-equipped aircraft that are within range. Most aircraft are not transmitting position information at this time, so don't be surprised to see real-time tracking of only a fraction of the total ICAO identifiers that are displayed. Congratulations, you are now viewing your own virtual radar!

Virtual Radar Server offers many features and options that are too detailed to attempt to describe here. With a bit more configuration you can put your map page live on the internet for others to view, and better yet, send your raw data to ADS-B "hub" sites that aggregate data from many locations to provide up to a global view. One such hub is operated by the developer of *ADSB#*, and can be enabled by simply clicking the box on the *ADSB#* control panel. Change the NETWORK ADDRESS in *VRS* to SDRSHARP.COM and you will see your data along with that from other *ADSB#* users around the world. Clearly, with this low-cost solution, it won't be long until a global network of ADS-B monitoring stations will emerge.

The author of *VRS*, Andrew Whewell, has created an online forum for help and assistance. Most common questions can be found by via the forum **http://forum.virtualradarserver.co.uk/**.

Notes

[1]FAA ADS-B frequently asked questions: **www.faa.gov/nextgen/implementation/programs/adsb/faq/**.

[2]Analysis of the coaxial collinear antenna by L.B. Cebik, W4RNL: **w4rnl.net46.net/download/coco.pdf**.

[3]R. Nickels, W9RAN, "Cheap and Easy SDR," *QST*, Jan 2013, pp 30-35.

[4]*ADSB#* home page: **sdrsharp.com/index.php/a-simple-and-cheap-ads-b-receiver-using-rtl-sdr**.

[5]ADSB# Quick Start Guide: **www.atouk.com/wordpress/?page_id=237**.

[6]Virtual Radar Server home page: **www.virtualradarserver.co.uk/**.

[7]Windows Driver (*WinUSB*) installation using *Zadig*: **www.rtlsdr.org/softwarewindows**.

Photos by the author.

ARRL member and Amateur Extra class licensee Robert Nickels, W9RAN, was first licensed as WN0OHO in 1965 at age 14 while living in Nebraska. He has a BS degree from Fort Hays State University in Kansas and credits Amateur Radio as a major influence during his 35 year career in electronics manufacturing. He holds three US patents and recently retired from Honeywell where he held positions as a principal engineer, engineering manager, and strategic marketing director. Bob now heads up RAN Technology Inc, a business and technology consulting firm. An avid cyclist and cross-country skier, he enjoys Amateur Radio history and homebrewing, in addition to his main interest — collecting, restoring, and operating a growing collection of vintage electronics and boatanchor radios from the last five decades. You can contact Bob a 2645 East Dr, Freeport, IL 61032 or at **wran@arrl.net**.

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W1AW Schedule

W1AW's schedule is at the same local time throughout the year. From the second Sunday in March to the first Sunday in November, UTC = Eastern US Time + 4 hours. For the rest of the year, UTC = Eastern US Time + 5 hours.

PAC	MTN	CENT	EAST	UTC	MON	TUE	WED	THU	FRI
6 AM	7 AM	8 AM	9 AM	1400		FAST CODE	SLOW CODE	FAST CODE	SLOW CODE
7 AM-1 PM	8 AM-2 PM	9 AM-3 PM	10 AM-4 PM	1500-1700 1800-2045	VISITING OPERATOR TIME (12 PM-1 PM CLOSED FOR LUNCH)				
1 PM	2 PM	3 PM	4 PM	2100	FAST CODE	SLOW CODE	FAST CODE	SLOW CODE	FAST CODE
2 PM	3 PM	4 PM	5 PM	2200	CODE BULLETIN				
3 PM	4 PM	5 PM	6 PM	2300	DIGITAL BULLETIN				
4 PM	5 PM	6 PM	7 PM	0000	SLOW CODE	FAST CODE	SLOW CODE	FAST CODE	SLOW CODE
5 PM	6 PM	7 PM	8 PM	0100	CODE BULLETIN				
6 PM	7 PM	8 PM	9 PM	0200	DIGITAL BULLETIN				
6^{45} PM	7^{45} PM	8^{45} PM	9^{45} PM	0245	VOICE BULLETIN				
7 PM	8 PM	9 PM	10 PM	0300	FAST CODE	SLOW CODE	FAST CODE	SLOW CODE	FAST CODE
8 PM	9 PM	10 PM	11 PM	0400	CODE BULLETIN				

♦ Morse code transmissions: Frequencies are 1.8025, 3.5815, 7.0475, 14.0475, 18.0975, 21.0675, 28.0675, and 147.555 MHz.

Slow Code = practice sent at 5, 7½, 10, 13, and 15 WPM.

Fast Code = practice sent at 35, 30, 25, 20, 15, 13, and 10 WPM.

Code bulletins are sent at 18 WPM.

♦ W1AW Qualifying Runs are sent on the same frequencies as the Morse code transmissions. West Coast qualifying runs are transmitted by K6YR and other West Coast stations on 3590 kHz and other frequencies. See "Contest Corral" in this issue. Underline one minute of the highest speed you copied, certify that your copy was made without aid, and send it to ARRL for grading. Please include your name, call sign (if any), and complete mailing address. Fees: $10 for a certificate, $7.50 for endorsements.

♦ Digital transmissions: Frequencies are 3.5975, 7.095, 14.095, 18.1025, 21.095, 28.095, and 147.555 MHz.

Bulletins are sent using 45.45-baud Baudot, PSK31 in BPSK mode and MFSK16 on a daily revolving schedule.

Keplerian elements for many amateur satellites will be sent on the regular digital frequencies on Tuesdays and Fridays at 6:30 PM Eastern Time using Baudot and PSK31.

♦ Voice transmissions: Frequencies are 1.855, 3.99, 7.29, 14.29, 18.16, 21.39, 28.59, and 147.555 MHz.

♦ Notes: On Fridays, UTC, a DX bulletin replaces the regular bulletins. W1AW is open to visitors 10 AM to noon and 1 PM to 3:45 PM Monday through Friday. FCC licensed amateurs may operate the station during that time. Be sure to bring your current FCC amateur license or a photocopy. In a communication emergency, monitor W1AW for special bulletins as follows: voice on the hour, teleprinter at 15 minutes past the hour, and CW on the half hour.

W1AW code practice and CW/digital/phone bulletin transmission audio is also available real-time via the *EchoLink Conference Server* W1AWBDCT. The conference server runs concurrently with the regularly scheduled station transmissions.

During 2014, Headquarters and W1AW are closed on New Year's Day, Presidents' Day (February 17), Good Friday (April 18), Memorial Day (May 26), Independence Day (July 4), Labor Day (September 1), Thanksgiving and the following day (November 27 and 28), and Christmas (December 25). For more information, visit us at **www.arrl.org/w1aw**.