Use Your Tower as a Dual-Band, Low-Band DX Antenna

A low-profile, efficient vertical that uses a single coax feed line for 80 and 160 meters with no moving parts, traps, or tuners.

Theodore (Ted) Rappaport, N9NB, and Jim Parnell, W5JAW

You can transform your existing tower into a high-performing DX 80- and 160-meter vertical antenna that operates at the full legal-limit power. The antenna is very easy to install and maintain, creates a low-profile low-band antenna structure for existing tower owners, and provides simultaneous dual-band operation with a nearly ideal vertical radiation pattern.

The use of closely spaced parallel resonant antennas with a single feed line has been known for a long time.[1, 2] Similarly, shunt feeding a tower is well known — see John Devoldere's classic book *ON4UN's Low-Band DXing*.[3] Ted Rappaport, N9NB, also developed a compact 160-meter transmission line antenna that offered low-noise reception.[4]

At N9NB's ridge-top location, two 65-foot-tall towers are spaced exactly 40 meters apart, and each tower (see the lead photo) supports a two-element, 40-meter Yagi antenna 72 feet above ground, a 10/15/20-meter tribander at 67 feet, and a low tribander at about 20 feet. N9NB had installed 30 radials beneath each of the towers, anticipating the day when the towers would serve as vertical transmitting antennas for a two-element vertical phased array for 80 and 160 meters. Here, we focus on the design and construction of a single dual-band vertical using a single tower.

Designing the Dual-Band 80/160-Meter Vertical

Using *EZNEC*[5] to confirm the viability of the antenna design, we first determined the natural resonance of each tower with mounted antennas. The ON4UN book shows that a tower/antenna structure with an electrical length greater than 90° for 160 meters — that is, greater than a quarter wavelength, or 40-meter electrical length — is needed to effectively load a tower using a 160-meter gamma match shunt feed. A good 160-meter vertical radiation pattern can generally be accomplished for any tower that is more than 50 feet tall with a reasonably tall mast pipe and a standard triband Yagi on top. We modeled the N9NB tower and Yagi antennas in *EZNEC* (see Figure 1). By feeding the tower in *EZNEC* with a current source connected between the tower structure and the ground, we found that each tower resonated at 1.56 MHz, or 105° of electrical length.

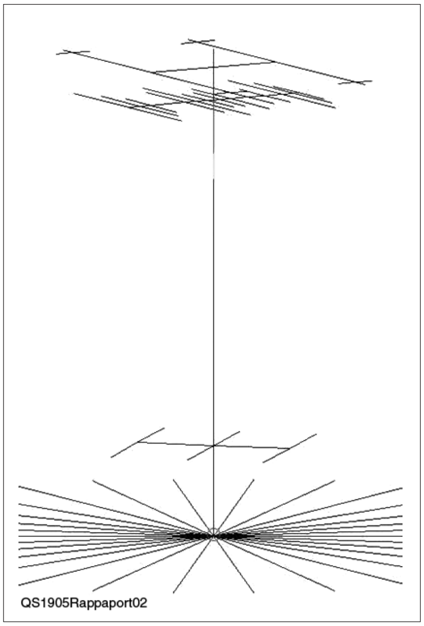

Figure 1 — An *EZNEC* model of the tower and antenna structure. A current feed modeled at the base was used to determine the resonant length of the tower/antenna system.

For insulated Yagi elements near the top of the tower, the driven Yagi element will be the only one that contributes to the overall electrical height of the tower, with a return current path through the Yagi's balun and coax feed line. The induced current in the Yagi's coax from radiation of the 160-meter shunt-fed tower can be high enough to damage the balun and/or the coax while reducing efficiency from current cancellation. Jim Parnell, W5JAW, solved this problem on a system at Jim George's, N3BB, station by shunting the drive point of the insulated driven elements of the Yagi at the physical connection where the balun of the Yagi is attached to the driven element. He used a center-tapped toroid to provide a safe path for induced currents along the tower during 160-meter operation. No such problems occur when uninsulated Yagi antennas are used on the tower. The lower-height Yagis, say 20 feet or closer to the ground, may be insulated or uninsulated and will have minimal impact on performance.

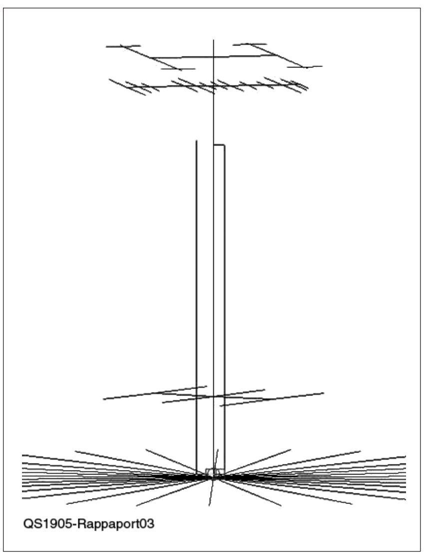

Figure 2 — *EZNEC* model of the dual-band vertical antenna system using the 80- and 160-meter feed system.

The natural resonance of the tower/antenna structure is greater than 90° for 160 meters. Through *EZNEC* simulations (see Figure 2), we found that a vertical wire for 80 meters placed 2½ – 3 feet away from the tower on the other side worked as a 0.21-wavelength-long, 80-meter vertical. Then, a shunt-fed gamma match at 160 meters could be used on the other side of the tower in tandem with the 80-meter parallel vertical wire for simultaneous resonance at 80 and 160 meters, without sacrificing radiation efficiency in either antenna.

The computer simulations showed that the 80-meter antenna would have a radiation resistance of only 10 – 15 Ω, that the resonant point could vary by up to 50 kHz with very small changes in spacing from the tower, and that the 80-meter antenna would have very little impact on the 160-meter vertical performance or matching. This result inspired us to consider using a single coax balun at the base of the tower, with a single SO-239 coaxial connector to 50 Ω coax to the shack. One parallel feeding mode was with the "hot center" of the coax to feed the 160-meter gamma match capacitor, and

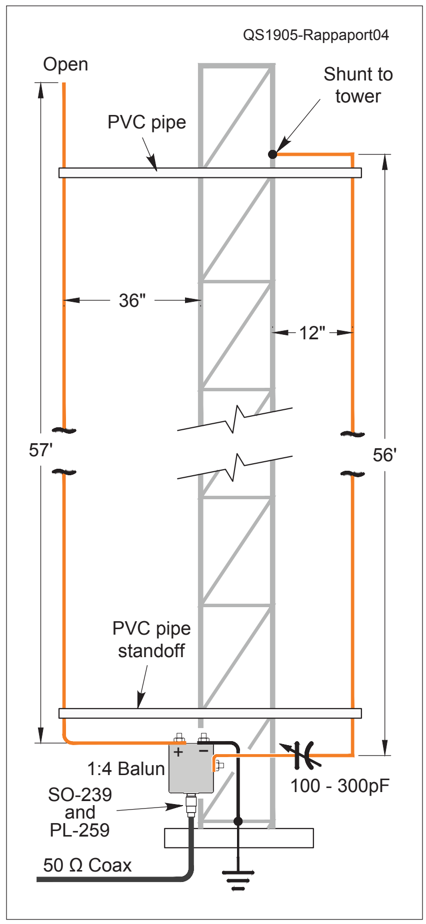

Figure 3 — Feed system design of the dual 80/160-meter vertical antenna using an existing tower and a single coax.

the other would be the 1:4 balun transformer output used to connect to the 80-meter vertical wire (the "+" lug) and the ground system (the "–" lug), as is shown in Figure 3. We spoke with the owner of Balun Designs, who added a hot center lug to the standard Model 1435 1:4 balun (see Figure 4) at nominal cost.

Based on *EZNEC* modeling and field tuning, the 80-meter antenna would be sensitive to the spacing of wires near the ground and the base of the tower, as well as to the spacing from the top of the wire to the tower. The *EZNEC* SWR predictions with the 80-meter vertical optimized to 3,530 kHz and the 160-meter vertical optimized for 1,825 kHz were encouraging. A feed impedance of 12.5 Ω is used for the 80-meter antenna. The *EZNEC* modeling revealed an ideal gamma match capacitance value of 270 pF when the 80-meter vertical wire was 57 feet tall and optimally spaced 3 feet away from the tower. Along the opposite side of the tower was the 56-feet-tall 160-meter shunt wire, spaced 1 foot away from the tower, and shorted to the tower at the top. These dimensions do vary as a function of tower size and diameter. The N9NB tower is comparable to Rohn 65. *EZNEC* simulations showed that the radiation pattern and gain of both the 80-meter and 160-meter verticals are within a fraction of a dB of a theoretical full-size quarter-wave vertical antenna in the clear and over an average ground. Encouraged by the modeling results, we set out to build the single coax-fed dual-band vertical.

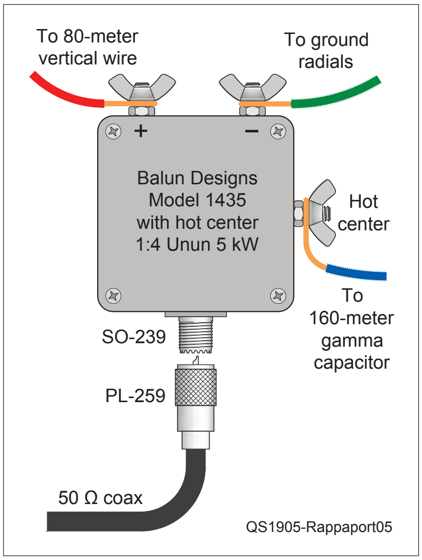

Figure 4 — Schematic of the Balun Designs model 1435 with hot center modification, and how to feed the structure.

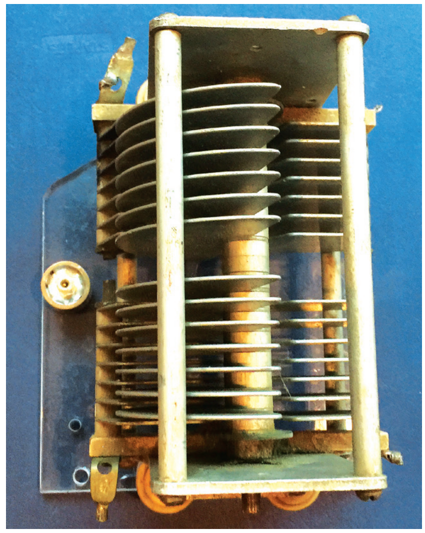

Figure 5 — Variable capacitor and doorknob capacitor mounted on Plexiglas. Holes are drilled to allow easy wiring of the components.

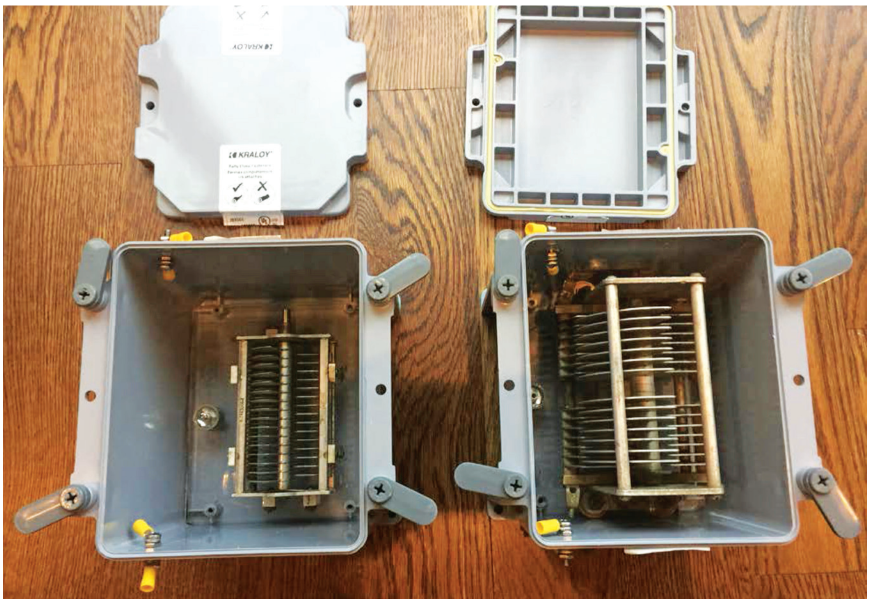

Figure 6 — The gamma match capacitor is comprised of a variable capacitor in parallel with a doorknob capacitor, both mounted on acrylic glass in the junction box assembly. Weep holes allow for draining condensation.

Building the Antenna

Table 1 lists the components used to construct the dual-band vertical for a single tower. The weather resistant, NEMA-rated junction box JBX666 by Kraloy houses the gamma capacitor circuit, which was built from a parallel combination of a variable capacitor and a doorknob capacitor, each rated at 5 kV and mounted inside the junction box on acrylic glass. The acrylic glass was cut to fit into the bottom of the box, and stainless-steel screws and lugs provide a connection from the gamma capacitor to the balun and shunt wire (see Figure 5). The gamma match capacitor is comprised of a variable capacitor in parallel with a doorknob capacitor, both mounted on acrylic glass in the junction-box assembly (see Figure 6).

Schedule 40 PVC pipe serves as a low-cost standoff for the parallel wires near the tower. Drill holes for the vertical wires a couple of inches from the ends of the PVC pipe. The wires can be properly spaced while easily passing through the spacers during adjustment. A PVC standoff must be used very close to ground where the vertical wires are brought into the

Table 1
Components for the 80/160-meter vertical on a single tower

Qty	Component	Comment
1	JBX666 junction box	Manufactured by Kraloy, available at many electrical supply stores
1	5⅝ × 6¾ × ¼ inch Plexiglas, Lexan, or perf board	To mount the capacitors in the junction box
2	20-foot pieces of ¾-inch schedule 40 PVC waterpipe	These are cut into three equal lengths of 6.66 feet at the store for easy transport in a car
12	1⅝-inch stainless-steel hose clamps	For mounting PVC spacer pipes to horizontal tower legs
1	Variable capacitor, 1 – 130 pF, 5 kV	Rating for legal limit
1	Doorknob capacitor, 180 pF, 5 kV	Rating for legal limit, available from Surplus Sales, Omaha, NE
1	Model 1435 1:4 unun with added hot center tap	Available from Balun Designs, Denton, TX
—	Assorted #12 AWG wire and lugs for vertical wires	To enable connections shown in Figures 3 and 4

balun and gamma match capacitor (see Figure 7). Provide weep holes in the center of the PVC pipe as well as in the weatherproof box to permit draining of condensation.

Tuning

EZNEC modeling revealed that the 160-meter antenna should be tuned first, before tuning the 80-meter vertical. Both antennas, balun, and ground radials must always be connected in parallel for all tuning. Connect an antenna analyzer to the balun to tune the gamma match capacitor and to determine proper lengths of the shunt wire and 80-meter vertical wire. Measurements should always be made with the antenna analyzer several feet away from the base of the tower or any of the antenna components, and without anyone touching the meter or any part of the antenna system. When measuring SWR, you should ideally measure within 5 or 10 feet of the balun feed, then again at the end of the coax in the shack.

At N9NB, the lower tribanders created a potential for the vertical wires to touch the Yagis in the wind, so an additional PVC pipe was used as standoff spacers.

With both the 80-meter and 160-meter antennas and the balun in the circuit, find the proper height at which to shunt-feed the 160-meter gamma match by trial and error. Start with the value suggested from *EZNEC* and move the shunt height in 1-foot increments while tuning the gamma capacitor for resonance. Having sufficient capacitance tuning range of about 100 pF – 300 pF on the gamma match is critical.

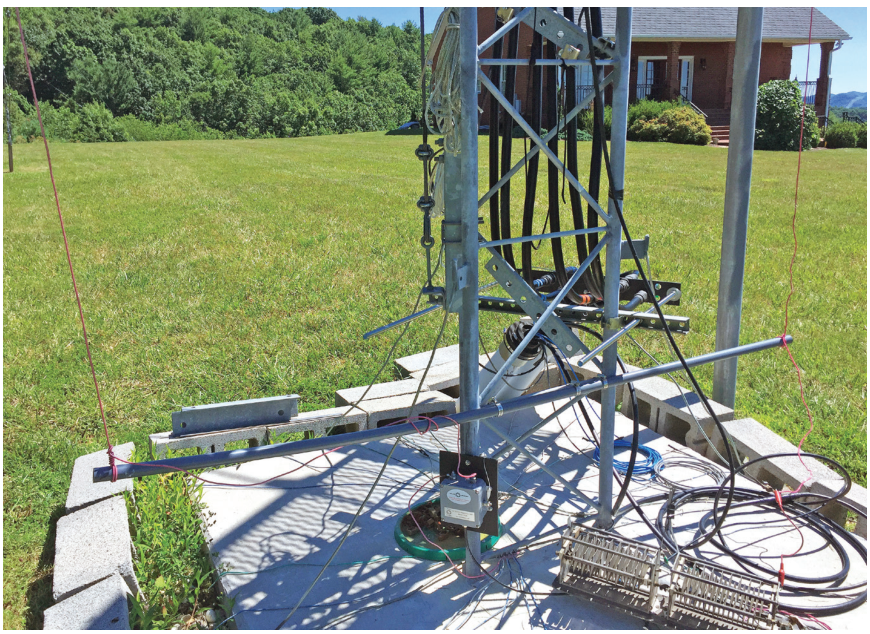

Figure 7 — PVC pipe, held by hose clamps, is used to space the vertical wires for optimal performance. Rope may be used to tie the 80-meter wire closer to the tower for tuning higher in the band.

Additional tuning can be accomplished by moving the PVC standoffs horizontally such that the wire spacing from the tower is varied. This can be easily accomplished by using stainless-steel hose clamps to hold and loosen the PVC spacers on the horizontal (climbing) bars of the tower.

A pulley is ideal for hoisting and lowering the 80-meter vertical wire during tuning. The optimal 80-meter vertical wire height was 58 feet above ground, and a range of 50 kHz could be tuned by moving the top end of the wire closer or further away from the tower on the top PVC standoff. Different tower assemblies will provide different values.

Performance Results

We measured SWR performance for 160 and 80 meters at the end of 120 feet of LMR 600 coax and tabulated the results in Tables 2 and 3. The measured SWR performance is a bit better than predicted in *EZNEC*. The relatively narrow 70 – 90 kHz 1.5:1 SWR bandwidth on 160 and 80 meters can be adjusted for different portions of the band by simple pre-set tuning adjustments at ground level.

Table 2
Measured SWR, 160-meter band

Freq., kHz	SWR
1,800	1.4
1,825	1.1
1,850	1.2
1,875	1.6
1,900	2.1

Table 3
Measured SWR, 80-meter band

Freq., kHz	SWR
3,500	1.4
3,525	1.2
3,550	1.1
3,575	1.3
3,590	1.5
3,600	1.9

The results in recent contest operations have exceeded expectations, with stations on the west coast reporting N9NB as strong as any other station, and with signal reports of the vertical being equal to or better than a reference dipole, depending on the time of evening and polarization of the other station. In fact, N9NB used a single vertical antenna to win the 2018 US low-power CQWW SSB contest. Tuning to the phone band in that contest was accomplished by tying the 80-meter vertical wire closer to the tower at head and arm height. As gratifying as the performance is, the fact that this antenna does not fall down in the wind makes it a permanent replacement for the dipoles and inverted L on the low bands.

Notes

[1]H. Groverman, W6HDG, "The Fence Fan Dipole (FFD) — A Quick, Easy and Inexpensive Multiband Antenna," July 2012, **eham.net**.

[2]T. Tinge, PA1M, "Multiband Wire Vertical," **www.pa1m.nl/pa1m/multiband-wire-vertical/**.

[3]J. Devoldere, *ON4UN's Low Band DXing*, ARRL Item no. 8560, available from your ARRL dealer, or from the ARRL Store. Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; or **pubsales@arrl.org**.

[4]T. Rappaport, N9NB, "160-meter transmission line antenna," *Ham Radio Magazine*, May 1985, pp. 87 – 91.

[5]Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

Photos by Ted Rappaport, N9NB.

Ted Rappaport, N9NB, has been a licensed Amateur Radio operator since 1975, and is on the faculty of New York University. He currently serves as Director of NYU WIRELESS, a leading academic engineering center that focuses on the wireless telecommunications industry. He is the David Lee/Ernst Weber Professor of Electrical and Computer Engineering in the Tandon School of Engineering. Ted also holds professorships in the NYU Courant Computer Science Department, and the School of Radiology at the NYU Langone Medical Center. Earlier in his career, he founded major wireless research centers at Virginia Tech and the University of Texas. Ted enjoys DXing and contesting. You can reach him at **tsrwvcomm@aol.com**.

Jim Parnell, W5JAW, became fascinated with electronics at age 6 and built his first radio shortly after. He was licensed as W5JAW in 1954. Jim obtained his commercial license and worked as a broadcast radio engineer throughout high school. He earned the BSEE at MIT and MSEE degree from LSU. His diverse career centered around R & D in scientific and analytical instrumentation, computer systems and peripherals, and robotics and control systems for semiconductor manufacture. After retiring from the industry, he worked with faculty and students as a technical consultant in the physics department at the University of Texas. He enjoys designing antenna systems for unusual and restricted environments.

For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.

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	1300		FAST CODE	SLOW CODE	FAST CODE	SLOW CODE
7 AM-1 PM	8 AM-2 PM	9 AM-3 PM	10 AM-4 PM	1400-1600 1700-1945	VISITING OPERATOR TIME (12 PM-1 PM CLOSED FOR LUNCH)				
1 PM	2 PM	3 PM	4 PM	2000	FAST CODE	SLOW CODE	FAST CODE	SLOW CODE	FAST CODE
2 PM	3 PM	4 PM	5 PM	2100	CODE BULLETIN				
3 PM	4 PM	5 PM	6 PM	2200	DIGITAL BULLETIN				
4 PM	5 PM	6 PM	7 PM	2300	SLOW CODE	FAST CODE	SLOW CODE	FAST CODE	SLOW CODE
5 PM	6 PM	7 PM	8 PM	0000	CODE BULLETIN				
6 PM	7 PM	8 PM	9 PM	0100	DIGITAL BULLETIN				
6^{45} PM	7^{45} PM	8^{45} PM	9^{45} PM	0145	VOICE BULLETIN				
7 PM	8 PM	9 PM	10 PM	0200	FAST CODE	SLOW CODE	FAST CODE	SLOW CODE	FAST CODE
8 PM	9 PM	10 PM	11 PM	0300	CODE BULLETIN				

♦ Morse code transmissions: Frequencies are 1.8025, 3.5815, 7.0475, 14.0475, 18.0975, 21.0675, 28.0675, 50.350, 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 various west coast stations on CW frequencies that are normally used by W1AW, in addition to 3590 kHz, at various times. Underline 1 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, 50.350, 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, 50.350, and 147.555 MHz. Voice transmissions on 7.290 MHz are in AM double sideband, full carrier.

♦ 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. The W1AW Qualifying Run texts can also be copied via the EchoLink Conference Server.

During 2019, Headquarters and W1AW are closed on New Year's Day, Presidents Day (February 18), Good Friday (April 19), Memorial Day (May 27), Independence Day (July 4), Labor Day (September 2), Thanksgiving and the following day (November 28 and 29), and Christmas (December 25). For more information, visit us at **www.arrl.org/w1aw**.