1 Motivation

From the point of view of efficiency, tuning an antenna to resonance at the frequency of transmission makes sense in that it ensures maximum transfer of power, which is all well and good until we QSY to another frequency, forcing a need to retune or acceptance of the impedance mismatch and reflected power in the feed-line.

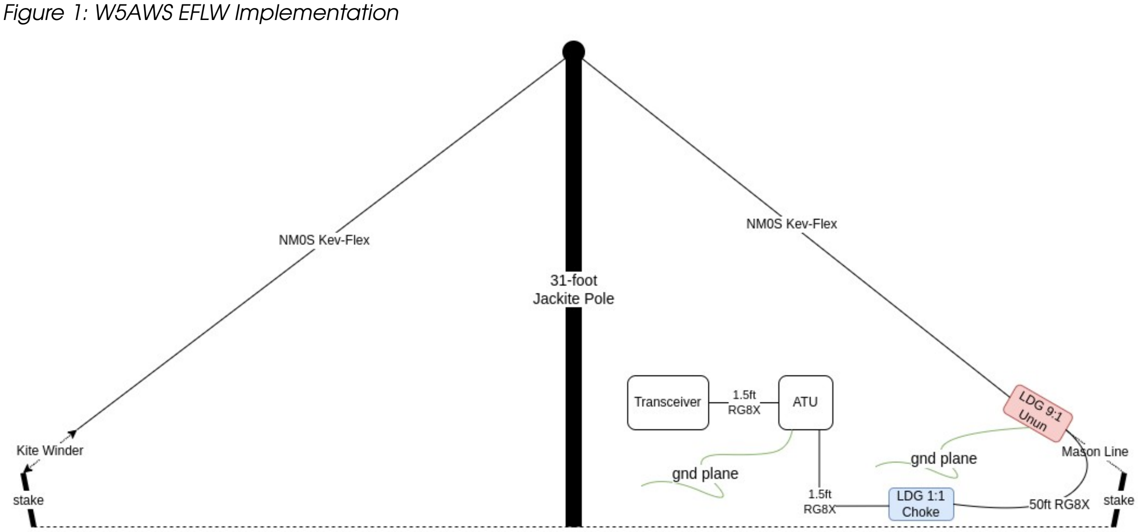
An End-Fed Half-Wave (EFHW) is an antenna that is a half-wavelength at the lowest frequency of operation, making the odd and even harmonics of the fundamental frequency available across the bands for which it is designed to work; even so, an antenna tuner is worth having to ensure a 50 Ω load to the transmitter, though not strictly necessary.

Having tried resonant antennas and a sloping EFHW, I thought to make things easier by using an End-Fed Long-Wire (EFLW) which is non-resonant on any operating frequency, in conjunction with a 9:1 UnUn, a choke, and automatic antenna tuner; the antenna itself configured either as a sloper or an inverted-V, the idea being to let the antenna tuner take care of business, leaving me to get on with making QSOs.

2 End-Fed Long-Wire

As a portable operator, I am working from a vehicle not Shanks' Pony, therefore my carrying capacity is greater. Figure 1 is a block diagram of the W5AWS EFLW antenna system.

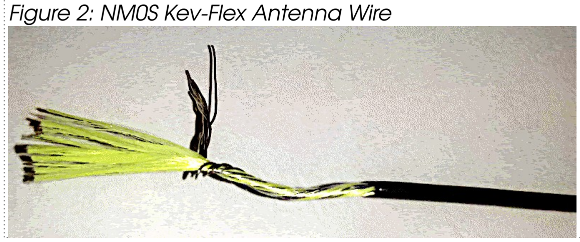
Figure 1: W5AWS EFLW Implementation



2.1 Antenna Element

Through the QRP Amateur Radio Club International (QRPARCI) user's group, I discovered Kev-Flex special-purpose antenna wire from David Cripe, NM0S, which means I can get 150 ft of wire onto a kite winder, enough for antennas down to the 160 m band.

Figure 2: NM0S Kev-Flex Antenna Wire



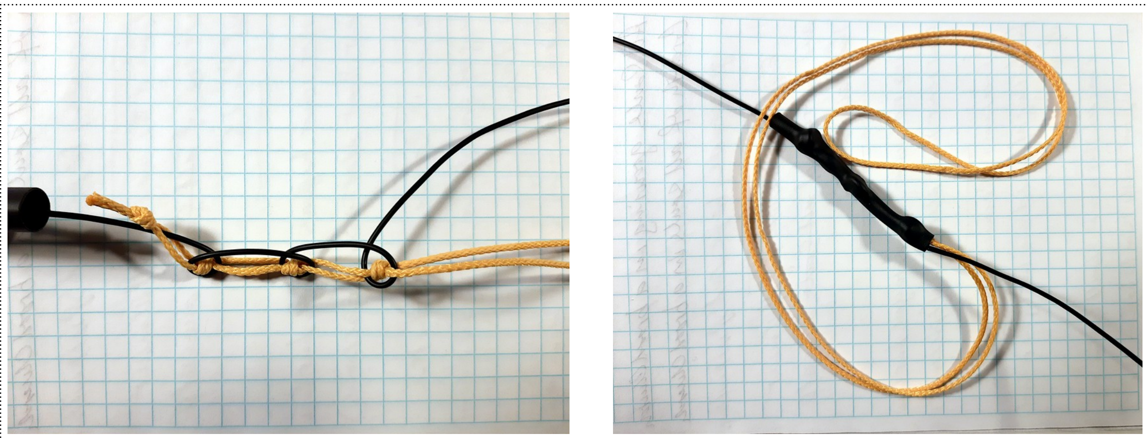
- Kevlar fiber core wrapped with six 30 AWG copper strands.
- Weather-proof black polyethylene (PE) insulation, 1/16" O.D.
- Weight: 16 ft per ounce
- Breaking-load: 130 lbs
- Velocity factor 0.97
- https://sites.google.com/nm0s.com/home/antenna-parts
- https://www.ebay.com/itm/255586927220

2.1.1 Antenna Terminations

At one end the kite winder terminates the antenna wire, that can either be hooked to a stake or stopped at the top of the mast, depending on whether the configuration is inverted-V or sloper.

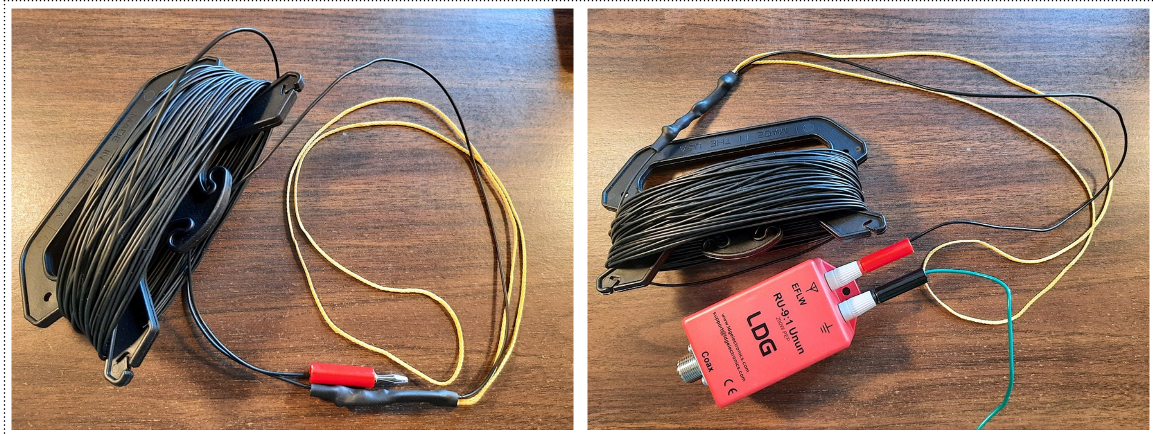
At the feed-line end I attached a lanyard to belay the antenna wire to an electric fence post, as shown in Figure 3, threading loops of antenna wire through knots in the lanyard. Any inductance resulting I suspect is insignificant overall. Heat-shrink tubing secures the loops and knots of the wire and lanyard.

Figure 3: Belaying lanyard



A red banana-plug terminates the antenna conductor, and a black banana-plug terminates one end of a short grounding pigtail; other end of the pigtail is terminated by an Anderson power-pole connector, which makes attaching a ground-plane wire easy as well as quick disconnection. Figure 4 illustrates this arrangement attached to an LDG 9:1 Unun. Quick disconnects also provide a measure of mechanical safety should someone become entangled in the wires.

Figure 4: Antenna conductor and ground plane terminations



2.1.2 Optimum Antenna Wire Lengths

Basically, the wire length should be anything other than a half-wave on any frequency of operation, but that means different things at different frequencies. Jack, VE3EED/SK, calculated some useful lengths for the center of the bands:

- https://www.hamuniverse.com/randomwireantennalengths.html

Mike, AB3AP, produced a useful development of the calculations by VE3EED, which can be found at the end of the link below.

- https://udel.edu/~mm/ham/randomWire/

To guard against link-rot, I excerpted the information in paragraph 2.1.2.1 , below.

2.1.2.1 Wire Lengths for Various Band Combinations

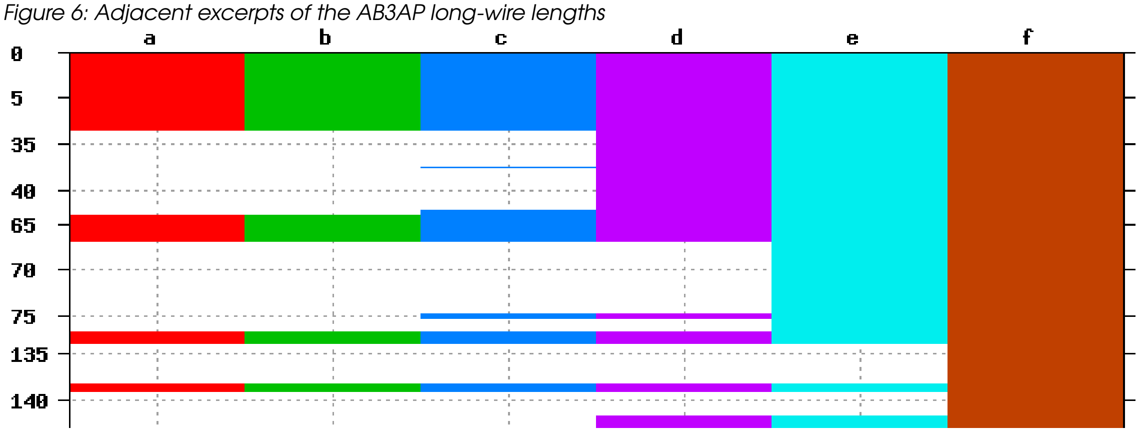
AB3AP says: *The graph below shows lengths to avoid for different collections of bands. The fewer bands, the fewer high impedance regions to avoid. You also want the antenna to be at least ¼-wavelength long for each band you plan to use. For instance, to work 40 m be sure the antenna is at least 10 m or 33 ft long. Use only the white gaps for your antenna lengths. ... If you want all the bands from 80 m up, W3EDP's 84 ft antenna, 17 ft counterpoise is probably the way to go. Notice from column f that there is no length giving low impedance for all US ham bands. You have to give up a band or two, like 60 m and 6 m, as shown in the column e.*

Figure 5: Band combinations in graph

Group	USA Bands
a	40-30-20-15
b	40-30-20-17
c	40-30-20-17-15-12-10
d	80-40-30-20-17-15-12-10
e	160-80-40-30-20-17-15-12-10
f	160-80-60-40-30-20-17-15-12-10-6

I excerpted the graph produced by AB3AP to show the most useful lengths adjacent to each other in Figure 6, making it easier to see in comparison with Figure 5.

Figure 6: Adjacent excerpts of the AB3AP long-wire lengths



As we can see in Figure 6, a shorter random wire-length of 35 or 40 feet nicely covers the 40, 30, 20, 17, 15, 12, & 10 meter bands, as shown in blue Group-C of Figure 5.

A medium-sized wire length close to either side of 70 feet covers 80, 40, 30, 20, 17, 15, 12, & 10 meter bands, as shown in purple Group-D.

Longer lengths at 135 or 140 feet cover 160, 80, 40, 30, 20, 17, 15, 12, & 10 meter bands, as shown in turquoise Group-E of Figure 5.

2.1.2.2 Measuring Wire Lengths in the Field

Numbers that we need remember are 35, 70, and 135 only, all of which are within scope of the 150 feet of Kev-Flex on the kite winder.

My spread arm-span, hand-to-hand is six feet; yours will be constant at some other footage. For me, to get thirty-five feet of Kev-Flex off the winder is five and a half arm widths plus a bit. For seventy feet is eleven and half arm spans of wire, and 135-feet is twenty-two and half spans.

Exact measurements are unnecessary. Close is good enough. The antenna tuner or matching unit will transform the impedance for the radio.

2.2 Mast

Instead of being constrained in my operations by the availability of convenient trees, I prefer to use a collapsible mast that can be placed in any open space to elevate the antenna element.

Tracy, VE3TWM, published some videos of his experience with Jackite masts, convincing me that they are worth trying. Jackite sell a reasonably priced 31 ft mast that is less than half the price of something similar from MFJ Industries.

- https://www.jackite.com/online-store/31-ft-Thick-Tip-Green-Fiberglass-Windsock-Pole-p78587348

I improved the mast guying by using 3⁄16″ RopeRatchets between the tent pegs and the mason’s line loops threaded around the 2″ Schedule-40 PVC mounting pipe. Before field-deployment, I did a test installation at home, as shown in Figure 7 and Figure 8.

- https://www.lowes.com/pd/Charlotte-Pipe-2-in-dia-x-5-ft-L-280-PSI-PVC-Pipe/3133043, cut to 3 ft length.
- https://www.lowes.com/pd/Marshalltown-500-ft-Fluorescent-Yellow-Nylon-Mason-Line-String/500184523
- https://www.roperatchet.com/products/3-16-ratchet-single-pack
- https://www.dxengineering.com/parts/dxe-tentpegs4

Figure 7: Mast mounting

Figure 8: Mast guying

Diameter of the PVC pipe is not wide enough to clear the butt-end cap of the mast. Combined tension of the guy lines causes the pipe to bear down on the end cap, pressing the butt of the mast against the ground, preventing it from kicking out due to the turning moment of the mast swaying in the wind.

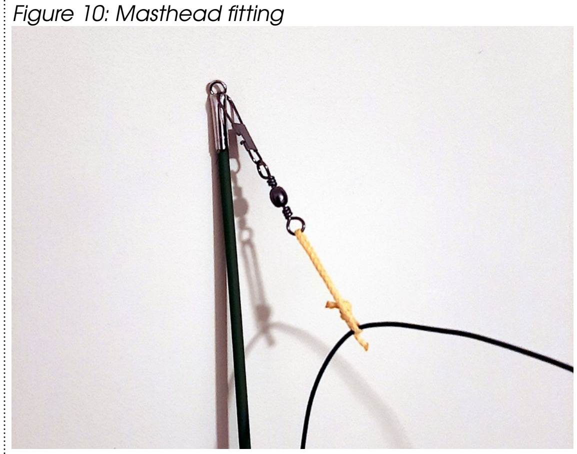
2.2.1 Masthead Fitting

On a pleasant March Wednesday, 2023, I operated in the picnic area of Osage Hills State Park, when I was the only person there and could use the space without annoying anyone else. It was a breezy afternoon that demonstrated a necessary improvement to the plain loop of Mason's line at the masthead to prevent the Mason's line and Kev-Flex wire from getting tangled.

At the WalMart Super Center, I found some barrel swivels with interlocking snaps in the fishing section; see Figure 9. I added a short piece of Mason's line, fastened in a loop with a reef knot, just big enough to allow passage of the banana plug and Kev-Flex; see Figure 10.

Figure 9: Barrel swivels

Figure 10: Masthead fitting



My original intention was to use two barrel swivels back-to-back, but I thought the metal of the interlocking snap would chafe the Kev-Flex insulation as the mast swayed in the wind. Instead, I decided to use a loop of Mason's line, which though strong is softer and easily replaced when it fails.

2.2.2 Stakes

Electric fence posts secure the ends of the inverted-V of Kev-Flex wire, as shown in Figure 11 at bottom left and a quarter up from bottom right corners.

- https://www.lowes.com/pd/Fi-Shock-1-in-x-3-38-ft-Plastic-Electric-Fence-Post/3006156

Figure 11: EFLW inverted-V installation

The antenna mast appears in Figure 11 about a quarter of the image width from the right edge.

Length of the Kev-Flex is twenty-two and half arm-spans long, which for me is about 135 feet. Figure 12 is a closer look at the 9:1 unun at the feed-end of the wire.

The black banana plug connects a pigtail terminated with an Anderson Power-Pole connector that joins it to a kite winder of wire unraveled under the inverted-V as a ground plane.

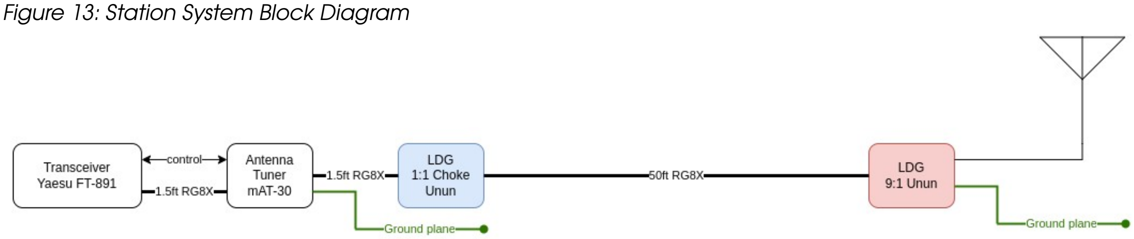
The red banana plug connects the end of the inverted-V to the antenna input of the 9:1 unun.

At the far end of the inverted-V, I hooked the kite winder with residual Kev-Flex over an electric fence post, and hooked a loop of Kev-Flex to the post to prevent it from falling off.

Figure 12: Feed-end with 9:1 unun

3 Station Field-configuration

Figure 13: Station System Block Diagram



3.1 Transceiver

In the field configuration shown in Figure 13, the Yaesu FT-891 is a very capable radio that I run at half its rated power output. Though capable, I am using it in its default configuration except for the RF power output and changing the function of one programmable button for tuner operation.

When one stops to consider how much is packed into boxes of tricks like the FT-891, one sees the result of a lot of engineering, ergonomic design, and compromise that makes the retail price seem quite reasonable. Naturally, though reasonable, the price is definitely a chunk of change and an investment that is worth protecting by avoiding damage to the RF power amplifiers by driving into a mismatched antenna load like a random wire, which makes an antenna tuner cheap insurance.

3.2 Antenna Matching Unit

Since the FT-891 can automatically adjust an external antenna tuner, it made sense to take advantage of the feature. Yaesu have antenna matching accessories, but they tend to be pricey. I opted for the Chinese mAT-30, available from DX Engineering:

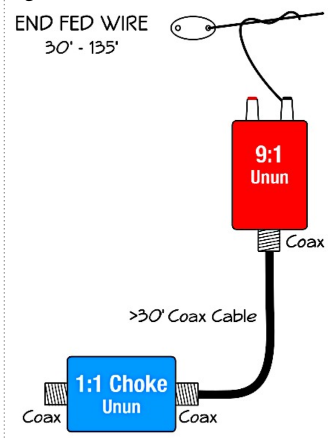
- https://www.dxengineering.com/parts/mtu-mat-30

Main attraction is that it is designed for Yaesu radios that support the Yaesu FT-30, FT-40, and FT-50 external tuners, and, crucially, is powered from the radio via the control cable—no batteries or additional power supply required.

3.3 Unun

A non-resonant EFLW presents an impedance of around 450 Ω, which requires transformation to 50 Ω. Connecting the EFLW direct to the mAT-30 would work since it is specified as capable of matching loads of 5 Ω to 1500 Ω. However, I thought it best to use a 9:1 Unun and a choke, as shown in Figure 14.

Figure 14: Unun and choke



LDG make an inexpensive range of impedance transformers in attractive water resistant packaging.

- https://www.dxengineering.com/parts/ldg-ru-9-1
- https://www.dxengineering.com/parts/ldg-ru-1-1

Figure 14 is an LDG illustration that I think is incorrect since it shows the antenna connected to the black instead of the red binding post.

3.4 Feed-line

In a non-resonant random wire antenna system, the coaxial feed-line has current flowing in the shield and acts as a ground plane, which means that a choke is necessary at the near end to prevent RF entering the radio. LDG recommend more than thirty feet of coax, so I used a standard 50 ft length of RG-8X, which allows placing the station in shade away from the antenna.

3.5 Ground plane

Since the feed-line does double-duty as a ground plane, additional elements aren't strictly necessary, but another element or two isn't difficult and can only help rather than hinder. To make things easier, I have a couple of ground lines stored on kite winders that connect to pigtails with Anderson Power-Pole connectors, which also break away easily should something or someone become entangled in the wires.

Figure 15: Ground plane elements

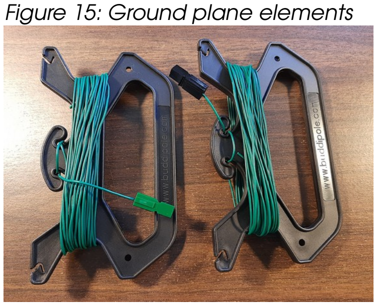


Figure 16: Unun ground pigtaill

Figure 17: mAT-30 ground pigtail

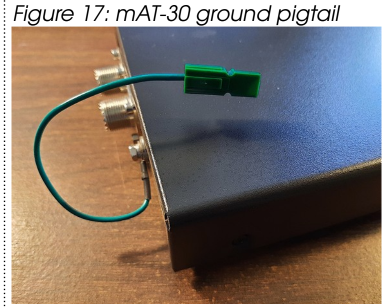


Figure 15 shows the ground-plane elements; the pigtail for Unun grounding appears in Figure 16, and the pigtail for antenna tuner grounding appears in Figure 17. Grounding radial for the 9:1 unun I lay on the ground in-line and under the radiating element of the antenna. Grounding radial from the tuner lies on the ground in an arbitrary yet convenient direction, the system works whether the radial is present or not.

4 Operation

On a quiet morning mid-week for testing, I went to Chandler Park in Tulsa where I erected the antenna in a north-south orientation with the station configuration as shown in Figure 13.

Mid-morning in the park, there were very few people present, which gave me plenty of unoccupied space and allowed me to erect 135 feet of End-Fed Long-Wire.

I made some measurements with my antenna analyzer to see what the SWR plots look like on the bands, connecting the analyzer in place of the antenna tuner.

Scan resolution of the analyzer was 200 points. Maximum resolution of 1,000 points is possible, but with a corresponding increase in the time needed to scan.

On another occasion, I should look at the phase, impedance, and return loss plots too.

Previously, I set the power output of my transceiver to 50W, which is half maximum power available and despite the fact that there is ample power in my 40 Ah Bioenno LiFePO4 battery to support full-power operation. I tend to agree with the concept of using just enough power to communicate.

To be sure of making contacts, I looked at the Parks On The Air (POTA) web-site on my mobile telephone, beginning with 10 meters:

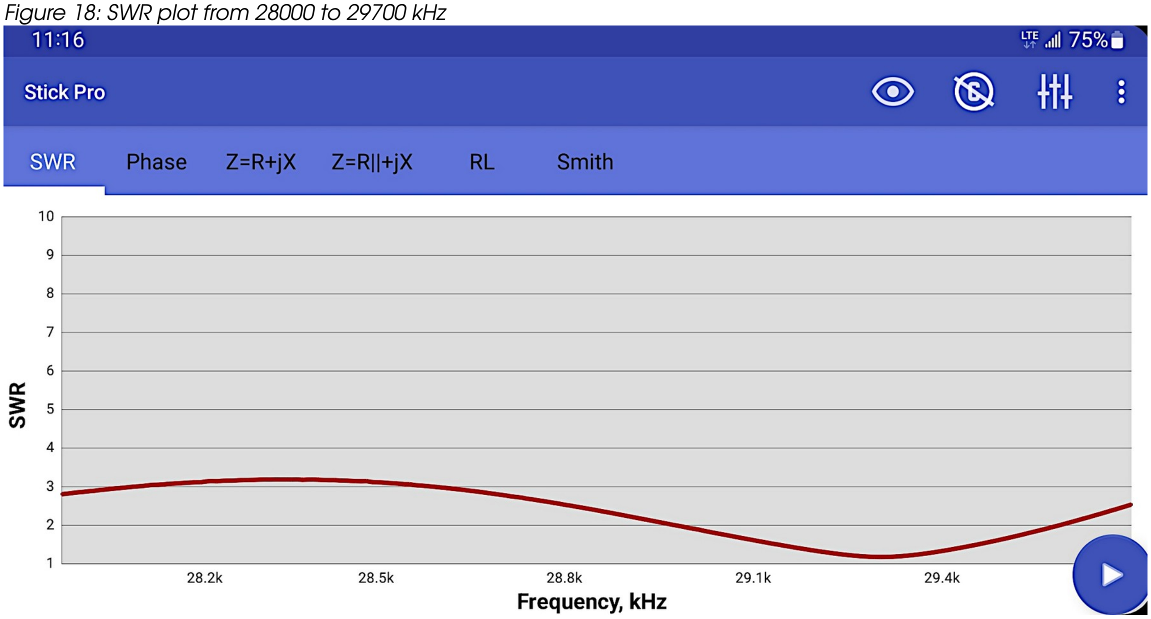
- https://pota.app/#/

At first, I listened with the antenna tuner disengaged. When I tuned to a POTA activation I engaged the tuner, forced a tuning cycle, then waited for an opportunity to announce my call-sign.

4.1 10 meters

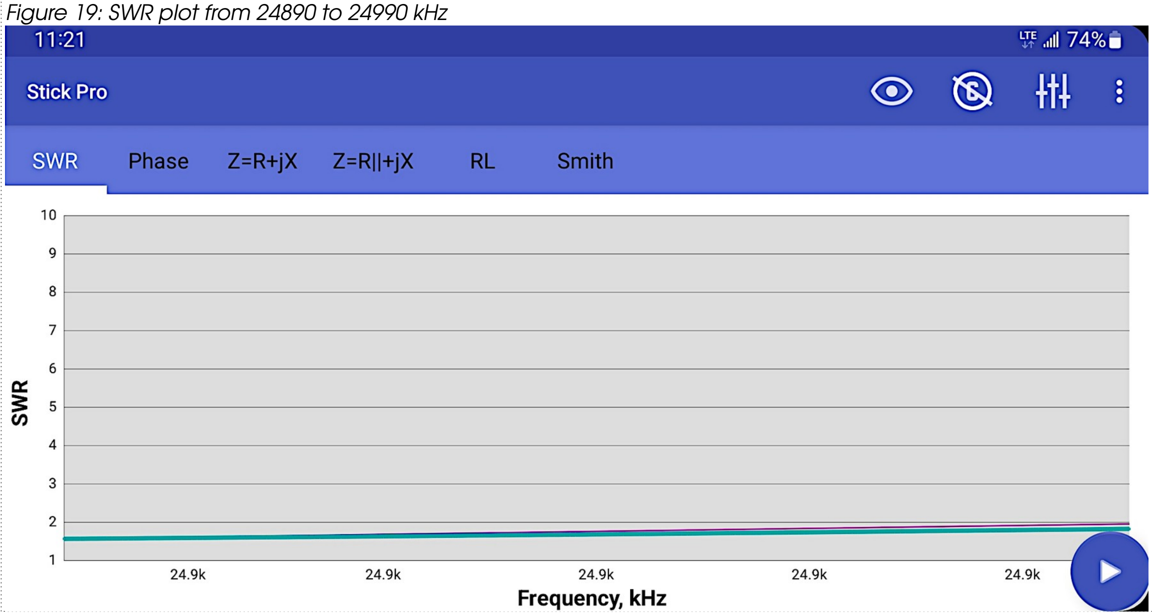
On this band, there was a lot of static, electrical noise, and traffic to the point of activators having to manage the mini pile-ups of hunters. My location in the park was near the flag pole with no power lines or other obvious sources of potential interference. After a couple of unsuccessful attempts to make myself heard, I decided to QSY to another band that had POTA activators.

Figure 18: SWR plot from 28000 to 29700 kHz



4.2 12 meters

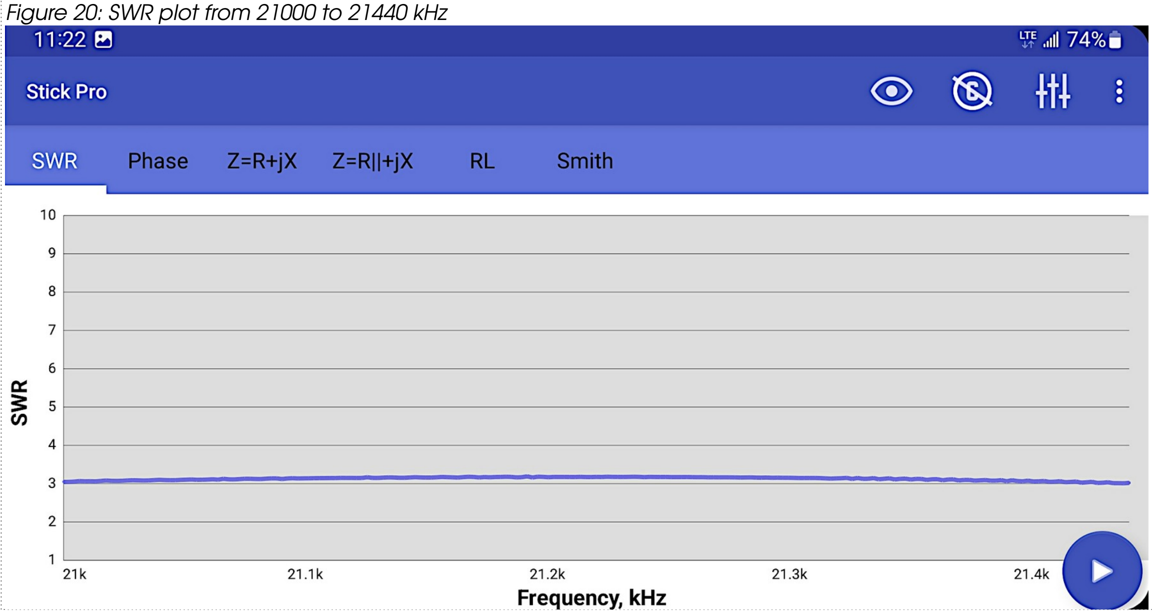
Figure 19: SWR plot from 24890 to 24990 kHz



4.3 15 meters

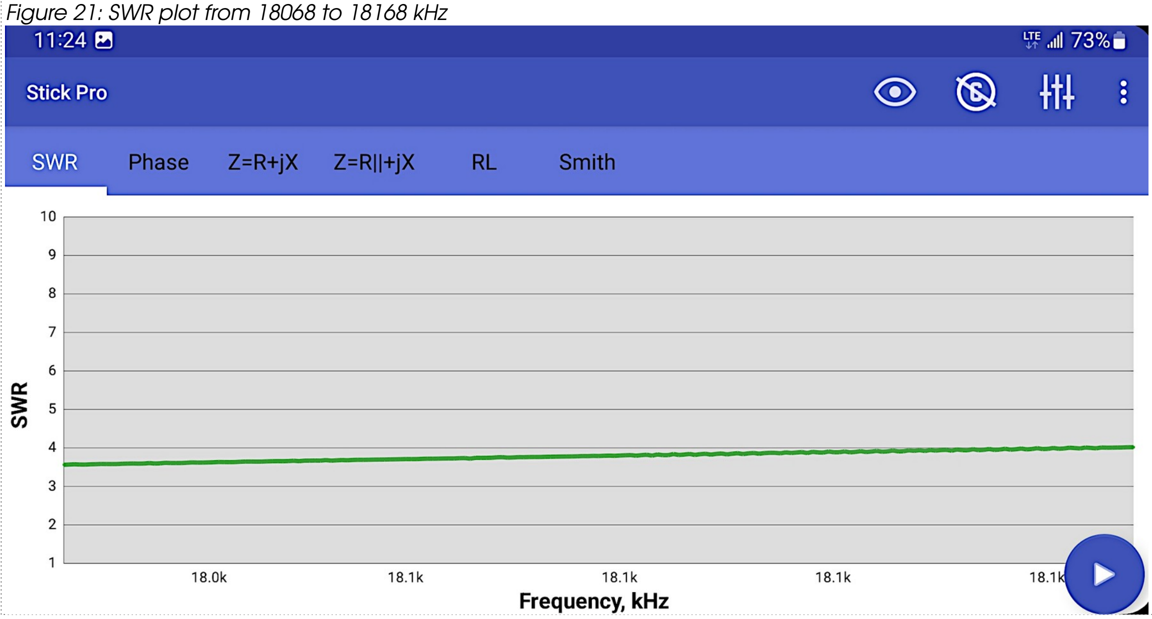
Electrically, the 15-meter band was much quieter than the 10-meter band, and there was only one activator who I managed to work, W1WRA in Silver Lake State Park, New Hampshire (FN42es), on 21321 kHz. The Maidenhead square distance and bearing calculator by N0UK, via this link https://www.chris.org/cgi-bin/calmdb, reports that FN42es is 1,383 miles away from EM16xd on a bearing of 063 degrees. W1WRA reported receiving my signal at 55; I received his signal at 58.

Figure 20: SWR plot from 21000 to 21440 kHz



4.4 17 meters

Figure 21: SWR plot from 18068 to 18168 kHz

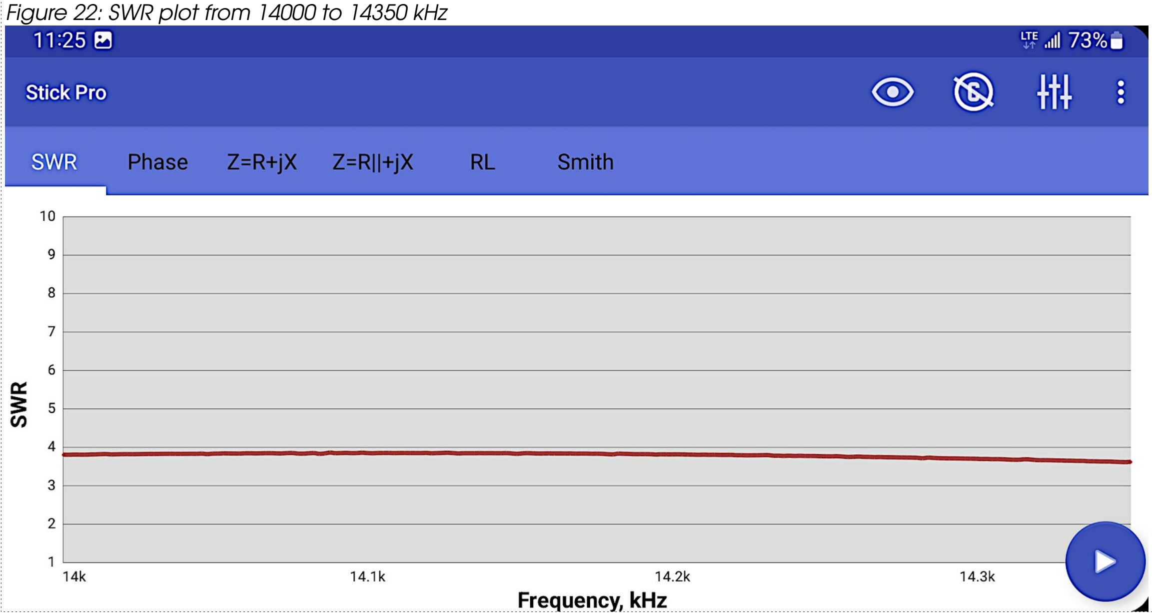


4.5 20 meters

There was a fair amount of activity on 20 meters, as there often is during the day.

I made contact with NV4H on 14270 kHz who was activating park K-3612, Charlotte Harbor Preserve State Park in Florida (EL86vu), 1,042 miles away on a bearing of 124.4 degrees. NV4H received me at 59; I received him at 58.

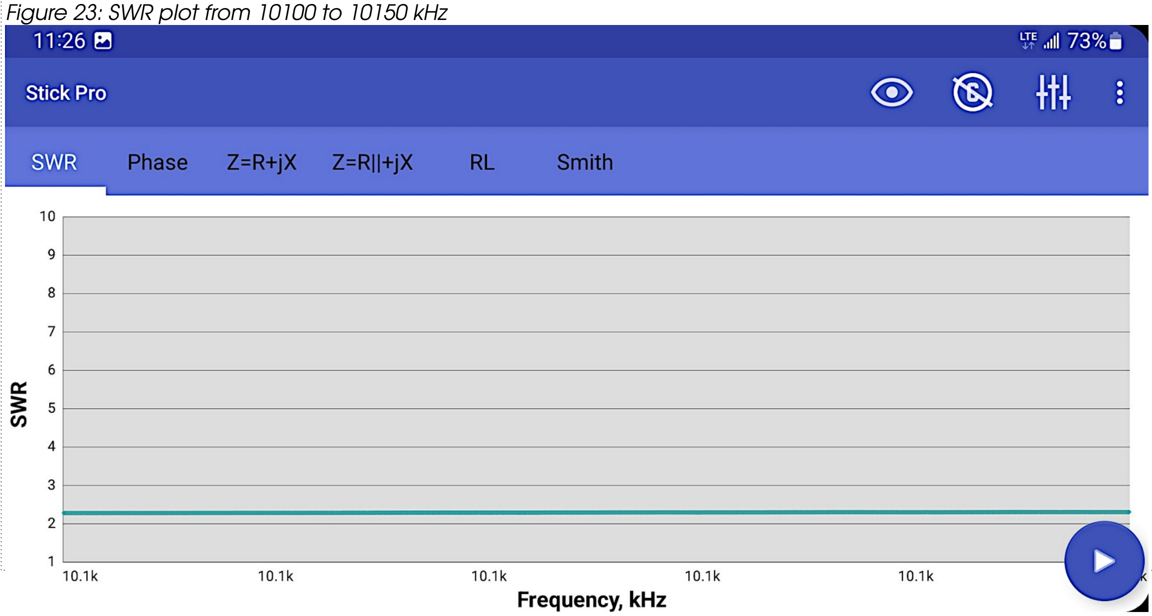
Figure 22: SWR plot from 14000 to 14350 kHz



Another contact I made with KC3RGV on 14237 kHz who was activating park K-1409, Raccoon Creek State Park in Pennsylvania (EN90sm), 901 miles away on a bearing of 066 degrees. KC3RGV received me at 58; I received him at 59.

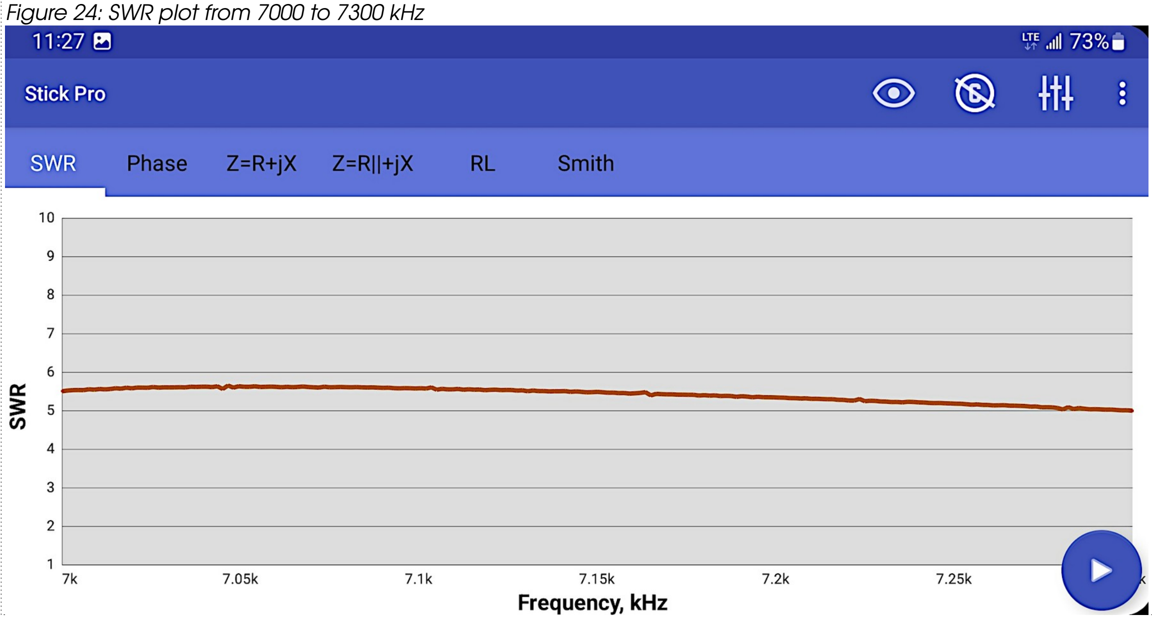
4.6 30 meters

Figure 23: SWR plot from 10100 to 10150 kHz



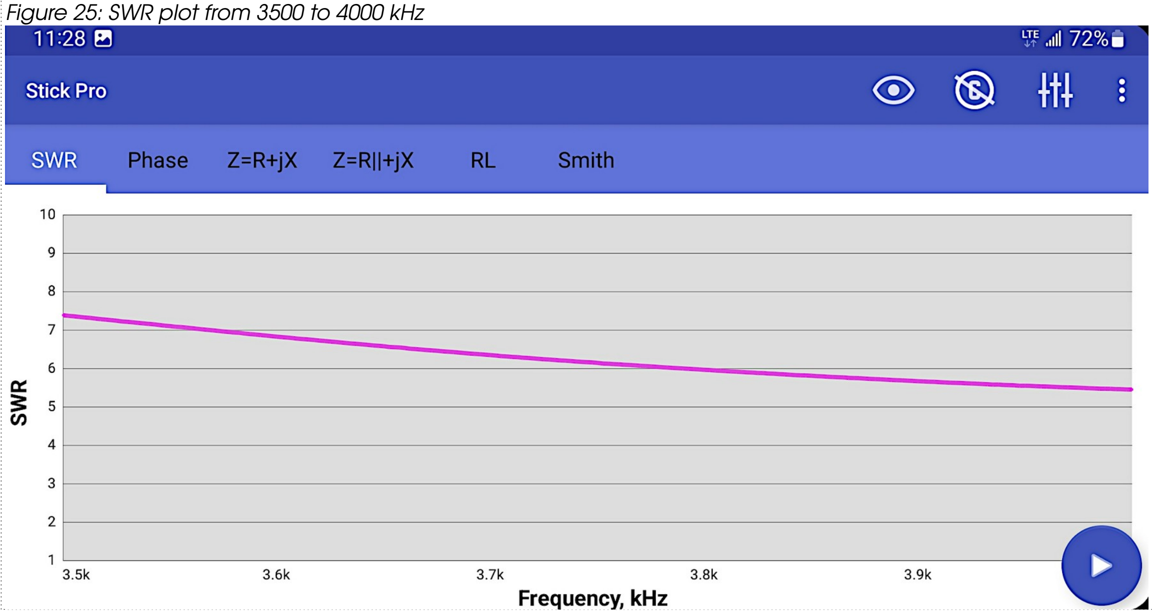
4.7 40 meters

Figure 24: SWR plot from 7000 to 7300 kHz



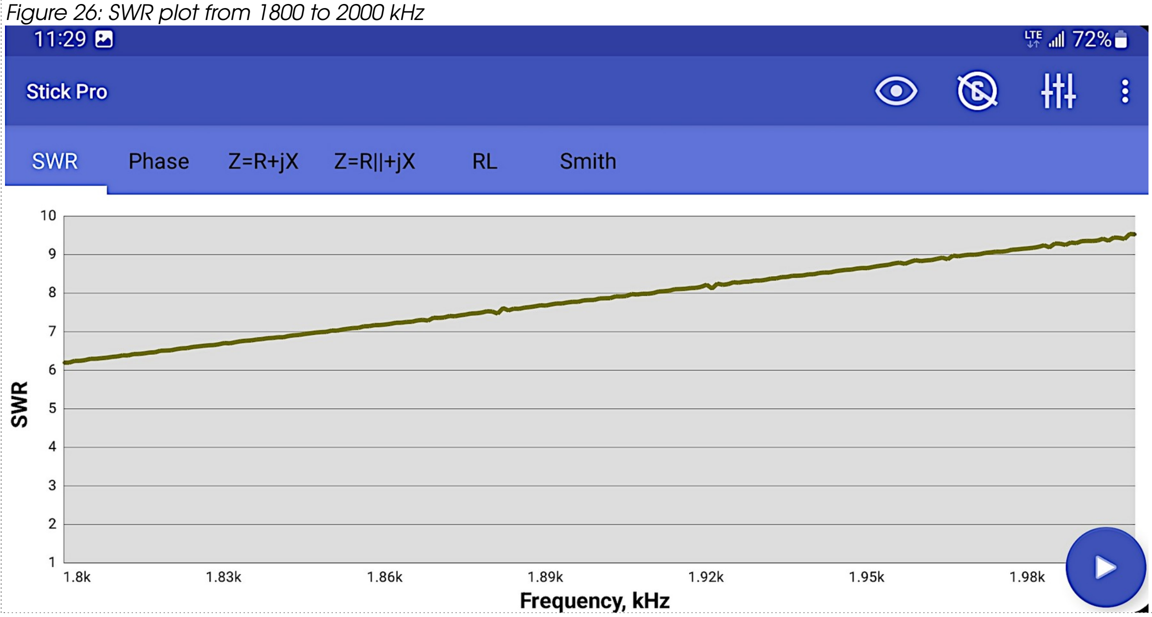
4.8 80 meters

Figure 25: SWR plot from 3500 to 4000 kHz



4.9 160 meters

Figure 26: SWR plot from 1800 to 2000 kHz



5 Conclusion

Having satisfied my curiosity about the 135-foot EFLW with three contacts on the shorter wavelengths at distances from 900 to 1,400 miles, I decided to go home for lunch. It is an inconvenient antenna size though inverted-V configuration does mitigate the antenna footprint somewhat. However, it is good to know that access to the 160-meter band is relatively easy.

A 72-foot EFLW inverted-V antenna offers non-resonant access to bands 80 through 10 meters, except 60 meters, in a more compact arrangement (Figure 6), about 36 feet between the ends of the antenna.

An interesting 40 through 10 meters antenna possibility, horizontally compact, is an almost vertical EFLW antenna made from six arm-spans, 36 feet, of Kev-Flex with the kite winder at the top of mast and the feed-end belayed at the electric fence post. Weight of the kite winder with spare Kev-Flex plus any wind loading will bend the mast below its 31-foot vertical height to make the antenna an acute sloper. This is worth trying next time.