Being Heard on 160m

Low Band RF Ground Losses
Understanding Sparse Radials
How FCP is a Fix.

K2AV - Hamvention May 17, 2024

Many thanks to Tim, K3LR for the opportunity to present the FCP at Hamvention 2024.

Text is added below the PowerPoint slides where a vocal part of the presentation is needed for clarity or completeness. Since Dayton, the "outside-the-box" slide at the end was fleshed out with 3 July '24 status. "AVT" optimization is ongoing.

Much Deserved Credits:

Many thanks to Eric Wagner, NR4O, for time, intellectual and physical support for this presentation's validating experiments. Nothing beats help whose opinions you want to hear.

Over the years, beyond erecting their own FCP, many hams contributed much to progress and the knowledge base:

The Roughly Raleigh Rowdy Radio Researchers

K2AV W0UCE(SK) NR4O N4AF K4CIA N4CW W4KAZ WB6JZY N3ND K8OZ K9JWV(SK) VO1HP VE3MM KT3Y/KP2M US5WE HC1PF/IV3PRK MM0SAJ K2VCO/4X6GP NS9I N4DU DL2OBO N3HEE N1LN N4YDU DM4IM N4CY WR5O K5ESW NI6T K5AF

The RRRRR membership? VO1, VE3, KP2, US5, HC1, 4X6, DL2… ? Well…

Everything down here is Roughly Raleigh as viewed from the outer solar system.

A Brief K2AV Radio History

- ’58-’86, College, Wedding, Jobs. Common reasons.
- 7 moves. KY, DC area, NY. K4VDL, K3FKJ, W2HVA, K2AV.
- 8th and *final* move, ‘90, NC near elderly dear relatives.
- New property instant love. Heavily wooded.
- Drive splits front. Big house, shed in back.
- No 160m input to the purchase, not suited to radials. Poor early 160m attempts, but no intention of moving.
- Similar problems at WØUCE. What to do…
- Our woodsy back yard. Going to mess with that? Nah.

This is a very common life history pattern. Early turning into a family, moving for advancement or deployment. Later picking a retirement area for any number of reasons, with the latest move intended to be a permanent move.

K2AV moved to be nearer his dear mother-in-law as both she and her dwelling were getting old, fragile, and needed frequent attention.

Being nearer turned out to be a priceless advantage. And the woodsy lot was love at first sight.

Define “woodsy”?

Here's a view of our backyard and our version of "woodsy". Our decades-long enjoyment of this outranks Ham Radio. There *is* a tower back there, in the property's far northwest corner. Can you pick it out? The NW corner placement, invisible from kitchen window location, was selected precisely for that.

The tower could not be used for 160 support due to the inverted L design proscription "no trees inside the L's bend". See explanation on k2av.com. The property's only permanent clearing in the tree canopy is over or close to the house, so that's where the L is now.

No Place for Commercial Grade Radials

Excellent 80m EFHWL for nets. How to do 160m? Advice: EFHWL as 160 ¼ wave. Put down a few radials somehow.

Did it. But FT101ZD's 120W on 160 quite poor. Ditto MP.

Added AL-1200. Still much DX hear-no-work. K2AV much weaker than 1.5 kW stations with tower & 90x100' radials.

Other suggestions for Inv L didn't work any better.

WHY SO WEAK ??

That would take experiments, discovery, a decade.

LORAN was scaling down and new transceivers, including K2AV's FT101ZD, covered 160m. So how does one get on top band with a decent signal?

K2AV already had an excellent 80m end-fed half-wave L up for the traffic nets.

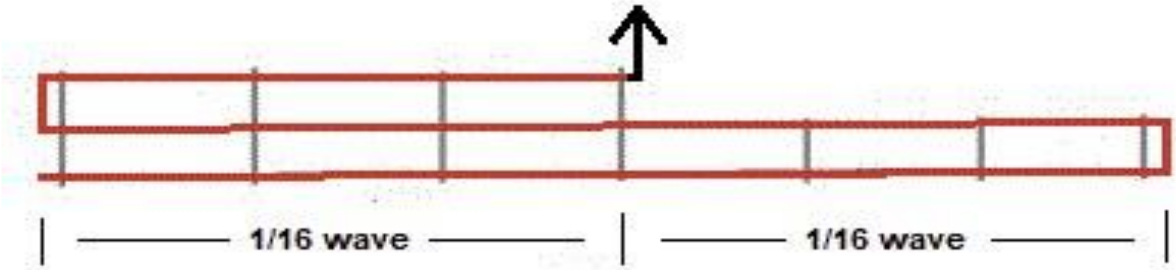
The North Carolina PVRC crowd were constantly pushing him to use that 80EFHWL as a 160m ¼λ and work the 160m contests. There was much well-intended how-to-do-that advice, unfortunately mostly involving sparse and irregular ¼λ ground radials. Anyone visiting understood no elevated radials.

Contests, Experiments, Discovery,
and a lot of Head-Scratching.
Nothing laying on the ground worked.
Finally, a break in the case.
Folding back two elevated radials helped WØUCE and others !!
The folding reduced RF fields at ground.
RF in the dirt was the enemy

A few irregular 125 ft ground radials really didn't work well for anyone. Via PVRC K2AV had met fellow NC transplant Jack, WØUCE. On a group hunch Jack and a Midwest WØ friend both tried two elevated radials folded back to center. The friend went from his 100W transceiver and 2 ground radials often not working *New* England, to working *Old* England, Germany, France, etc. That was just too juicy to ignore. Idea bulbs were flashing everywhere. It was easy to understand how wires at the fold produced almost equal opposite fields summing to almost net zero integrated fields at ground. We soon knew fields at ends and center of the folded radials were near net zero. Elsewhere net fields dropped less but significantly.

WØUCE tried 2 elevated 125' radials folded back to center.
Jack "feeling louder" on 160. Others did same, good results.
But both ends of Jack's overall 125' still in his neighbors' trees.
Some K2AV light bulb moments got to one wire folded 3 times.

5/16 λ Single Wire Folded CounterPoise



FCP with cord to two trees all in Jack's back yard! But before why this worked, did FCP improve serious contest results?

One thing to note here, K2AV was simply trying to get a shorter fold that would fit in Jack's back yard.

He didn't yet understand that he had created an electrical equivalent to two 33-foot-long raised radials, but with a usable feed impedance on 1.8 Mhz.

He didn't yet know that the FCP would have far less ground loss because the FCP's linear distance of ground induction was only a quarter that of regular 1.8 MHz ¼λ raised radials.

But before how & why, how well did it work? Did the FCP make any difference?

Early & Final FCP clearly made a difference

K2AV's three best CQ160CW efforts, claimed scores

1998: SOHP 786/55/43 = 227,458 26.5 hrs

Personal Best pre-FCP. All time best condx? MP, AL-1200, Inv L, 5 irregular 125 ft radials, W, N, E, no S, with many bends.

2011: SOLP 927/58/38 = 238,080 24.5 hrs

CQ Rank #4 USA, #1 W4. K3, Inv L over early FCP. NCJ Article.
227k HP => 238k LP +12-ish dB? Something going on.

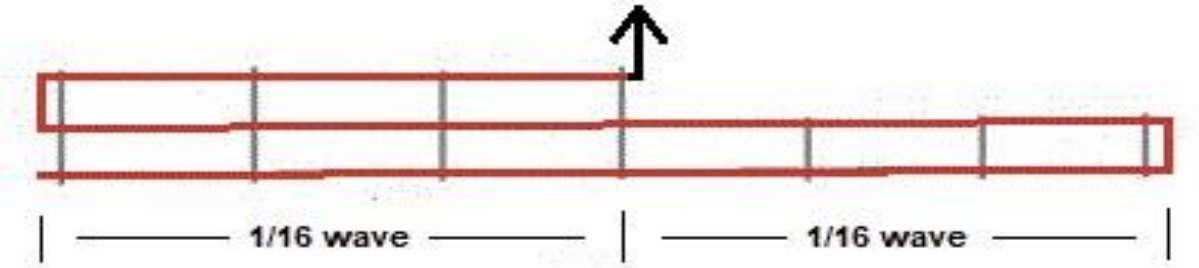
2020: SOAHP 1349/57/76 = 752,780 25 hrs

CQ Rank #7 USA, #1 W4 K3, KPA1500, Inv L over final FCP.

These are three serious K2AV efforts, each a personal best effort for the category, fulltime, maximum efforts in good low band years which demonstrate effects of counterpoise changes. 2020's 7th place out of 323 USA SOAHP entries in that super-competitive category was hard to believe, far, far past expectations. He simply did not think an inverted L could compete in a category with gold standard verticals over buried radials, 4-squares and saltwater overlook stations. The 2011 4th place in 336 USA SOLP entries was somehow more believable.

The log for the 1998 session was discovered in 2016 on a disk found inside a long removed 3.5" floppy drive. 1998 HP compared to the 2011 LP inferred a +12-ish dB counterpole improvement: 5 irregular on-ground radials versus early FCP.

5/16 λ Single Wire Folded CounterPoise, the FCP, produced the difference.



On 160m the FCP is 66 feet (20m) end -to-end.
Recommended height is 10 feet (3m)
5/16 λ FCP is not resonant. 160 FCP X ≈ -130 Ω

HOW, WHY does the FCP Work?

That's all it is. A very specific way to fold up 165 feet (50.3m) of bare solid copper AWG 12 wire. So how and why does that work?

Why FCP Works
Loss proportional to Length

Reduce dipole on ground (DOG) length, reduce ground loss

Height	Dipole	Meas FØ	Meas FØ R	Ω/foot
Gnd	+/- 100' *	1.550	125Ω	.63
"	+/- 66'	2.052	78Ω	.59
"	+/- 33'	3.852	28Ω	.42
"	+/- 76' **	many	75-200Ω	.49-1.3

+/- 33' lower FØ R a significant advantage over +/ - 66', +/- 100, +/- 76'.

*** Unable to measure +/- 132 on ground, not enough un-woodsy space.**
**** Pre-2012, many eastern NC DOG readings. FØ R range 75 Ω - 200Ω.**

This table consists of actual measurements. The first three rows were taken at an ad-hoc antenna range in K2AV's back yard, assisted and advised by NR4O. The last row is the summation of nearly a hundred measurements in the five or six counties around Raleigh, NC.

If the measured R in the first three rows is divided by the length, we get Ω/foot values. Note the consistency. The 66' .59Ω fits into the 76' .49Ω -1.3Ω range.

K2AV's five irregular 125' ground radials and inverted L fed at ground were losing at least ¾ of TX power. This begins to explain the 1998 to 2011 score difference.

Why FCP Works, 10 ft Height

Raising height reduces ground loss. Safer height.

7 ft Moonraker 160m Center-Load Whip over FCP or 2x100 ft radials

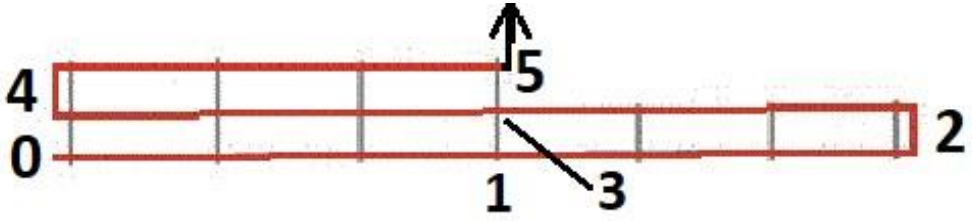
Height	FS dB V/m	FS mV	dB < FCP	Dipole FØ	FØ R
FCP 10’	-25.5	52	-	-	-
10’ (3.0m)	-28.8	36	-3.3	2.258	20
6’ (1.8m)	-30.0	32	-4.5	2.237	26
3’ (0.9m)	-30.2	31	-4.7	2.174	44
2” (5cm)	-38.5	12	-13.0	1.912	72

Field Strength measured on Potomac Inst. FIM-40 at 1.862 MHz
At 2 inch level, wire supported with paper bowls every three feet.

This table shows the huge difference between an FCP at 10’ and two long radials on the ground. We used 2” to get rid of variation due to odd and variable ground touching. In ground in the side yard not allowed by household authorities.

One more explanation for the difference in 1998 and 2011 CQ160CW scores. Underlines need for radials to be linear, long enough, dense enough, and uniformly spaced around entire compass. Sparse, irregular wastes your power.

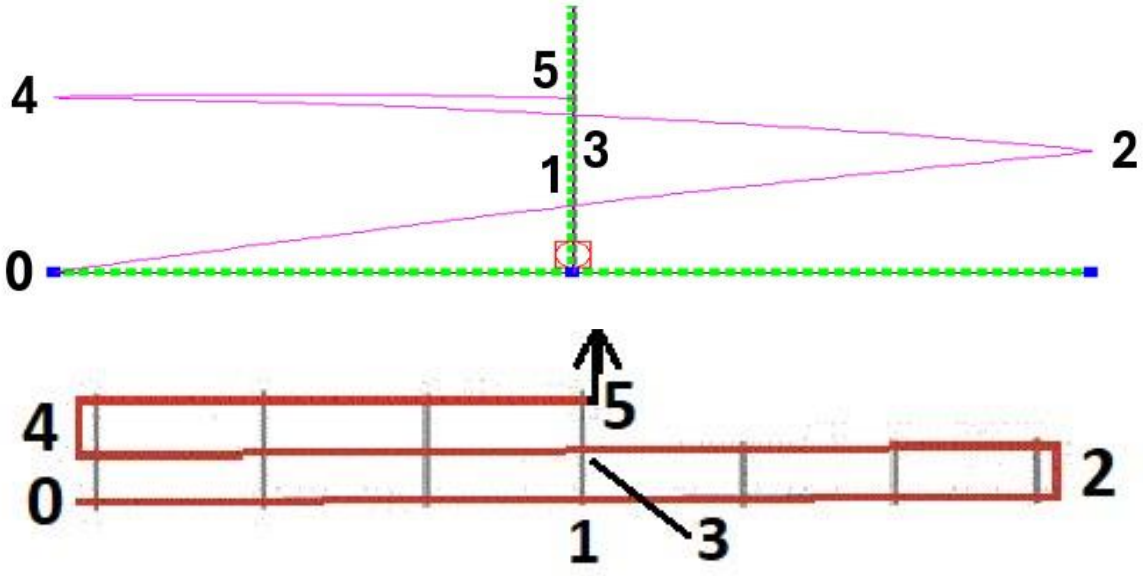
Why FCP Works, Folds



1/16 wave points are numbered 0-1-2-3-4-5
Point 5 is feed from isolation transformer FCP lug.
Minimum current at open end of wire, point 0
Maximum current at ¼ wave from end, point 4

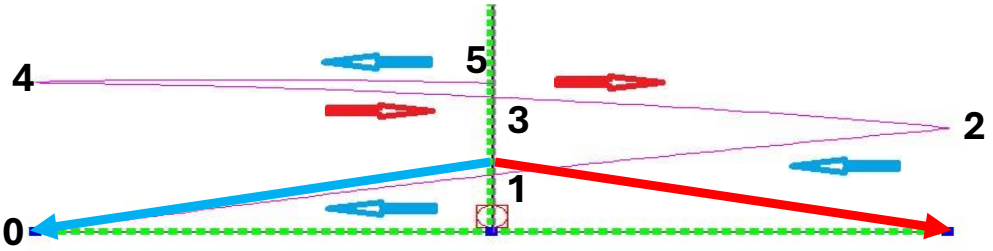
This numbering will be used on EZNEC
RF current waveform display, next.

Why FCP Works, Current on Folds



EZNEC/NEC4.2 RF currents from a typical FCP are shown in the violet traces. The zero value at point 0 increases along the way, via points 1-2-3 and levels out at point 4, going down a bit at point 5

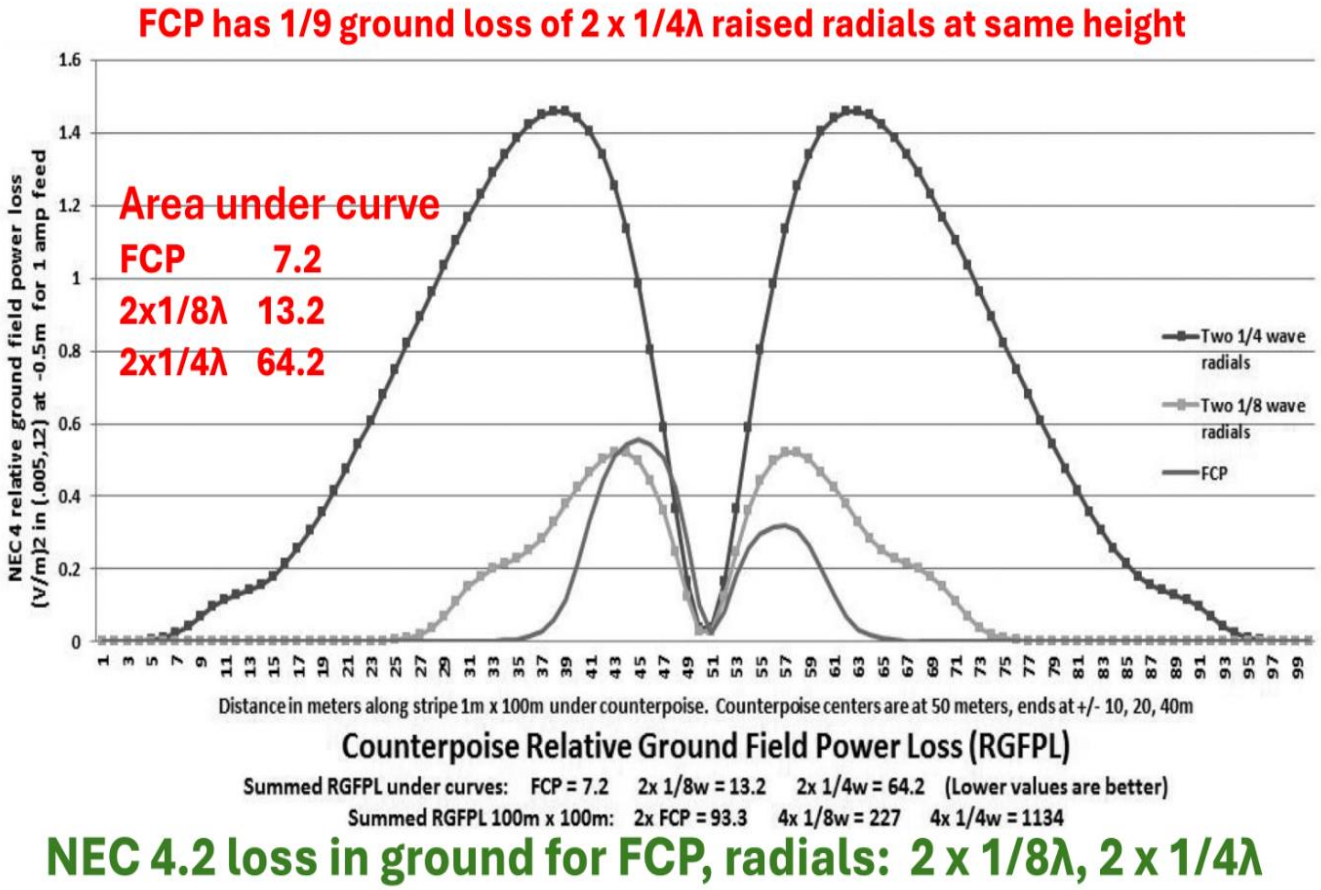
Why FCP Works, Wire RF Fields Add



Blue arrows show FCP current flowing to the left, red to the right. Short arrows represent current directions of the actual RF current waveform.
Long red & blue arrows show direction/amplitude of effective RF current waveform after fields have combined, all the power fed to the FCP.

Ground-loss-wise, we have replaced radial loss across 250' at whatever height with FCP loss across 66' at 10'. This easily explains measured -3.3, -4.5, -4.7 and -13 dB below FCP in the "Why FCP Works, 10 ft Height" table.

The FCP's effective current represented by the long blue and red arrows is nearly identical to modeled currents in a pair of 33 ft long, 10 ft elevated radials used on 160m. That was never recommended due to the monstrous -900Ω reactance involved. The FCP keeps the short length advantage and drops reactance to a manageable -130Ω.



The comparison is for all three curves at the same location. The absolute value of the loss depends on the location's ground characteristics.

The graph is from the May/June 2012 NCJ article on the FCP. Please note that some number of items in the article are obsolete, and have been replaced with current data on k2av.com. Always work an FCP, inverted L, etc, project from the current k2av.com. We have picked up a wealth of experience from FCP installers over the decade since publishing the NCJ article. See the "Loss List" on k2av.com for some of the worst loss offenders.

FCP issues worked out, Primitive to Final:

Do not trim FCP's last fold to tune SWR !!!!!!

Feed aerial over FCP with an isolation transformer!!

Build FCP with #12 bare solid copper wire.

Constant 4" (100mm) spacing of FCP folds.

Use minimum number of FCP spacers.

Maintain vegetation free 5 ft radius around FCP.

Avoid nearby miscellaneous conductors.

Do not mount FCP to, or close to tree trunks, or route parallel & close to any sort of long wooden beam.

Elevate FCP 10 feet above ground, if at all possible.

And yet more, if we had all day…

Got to thinking about it…a serious principle

An antenna system's AERIAL conductor(s): Intended to produce *maximum* possible RF radiation with *minimum* losses.

An antenna system's COUNTERPOLE conductor(s): Intended to produce *minimum* possible RF radiation with *minimum* losses.

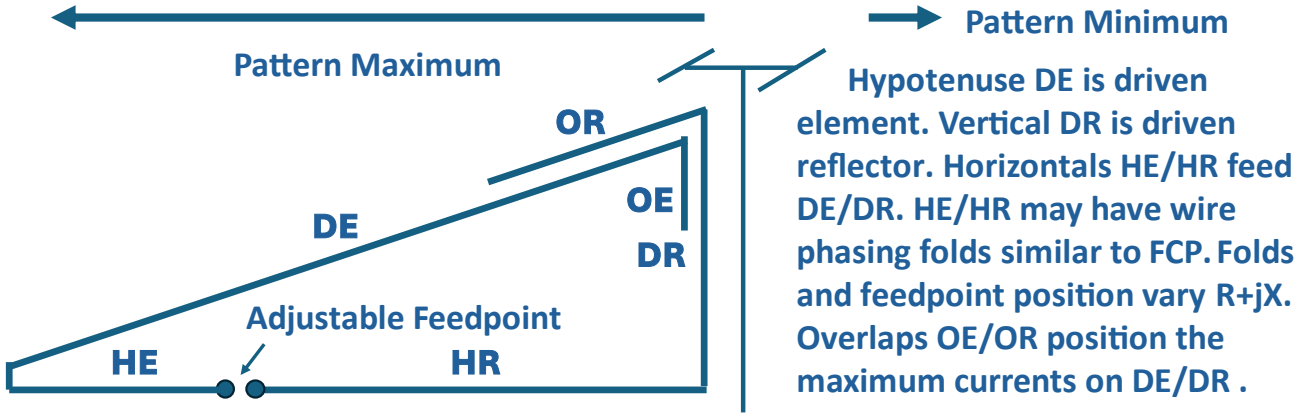
Hmmm….

Are we worrying about fractions of dB in aerial design? And ignoring multiple dB's of loss in the counterpole?

Many antennas designed for easily connected 50Ω feedpoint. Commercially, that sells more stuff. Do it yourself, it installs with less work.

What if we adjust the design first for best performance? And accept the idea that the feed point is miscellaneous and will need some matching work. Optimal inverted L + FCP is like that. Others? Like an AVT?

K2AV's version of a Triangle antenna, or "AVT "



AVT: Dual-driven-element 160m antenna with gain and front-to-back. • Each element is the counterpoise for the other, no separate radials or counterpoise. • AVT support: tower, tree or high building. • AVT reduced tower induction: Less loss from RF driven to ground at tower base and less RX noise & TX RFI from AVT ⇔ tower & cables. • As of July 2024, NEC4.2, ±45° forward gain ≥ reference AM BC vert. -3 dB ±117°. 180° -10 dB.

Status 3 July '24. Optimizing dimensions underway, not complete. Drawing above not to scale. Feed network design will be done after gain, pattern and ground independence optimization is settled. Trials fall, winter 2024.