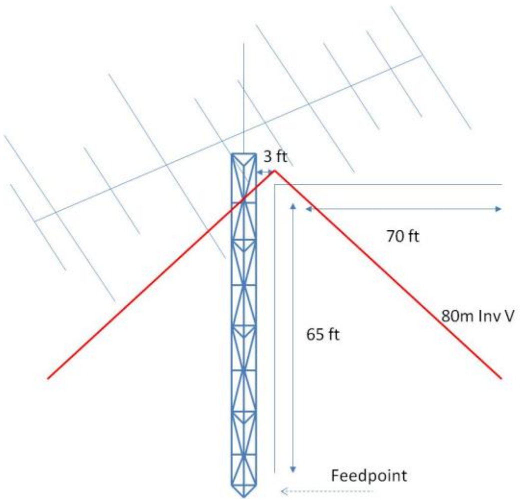
Subject: Inverted-L Problem and Resolution **Date:** August 26, 2013
Reference(s): **Author:** Jeff Crawford

Recently I installed a receive four-square which will be used on 160m, 80m, and perhaps 40m. Although the four-square works very well, I was immediately faced with a problem which began more than a year earlier.



I use an inverted-L antenna for 160m. It parallels, 3 feet away, my 72 foot crankup tower, making the corner in the "L" about 3 feet from the top of the tower. I have 30 radials emanating from the base of the inverted-L. It is fed at the base with an L-network to achieve nearly 1:1 VSWR in the CW portion of 160m. Routinely 1.2 – 1.4 KW are used with this antenna. Also on the tower is a Cushcraft XM-240 for 40m and a Force12 C31XR for 10-20m. Additionally, there is an inverted V antenna for the CW portion of 80m. This antenna is draped almost orthogonally to the inverted-L antenna.

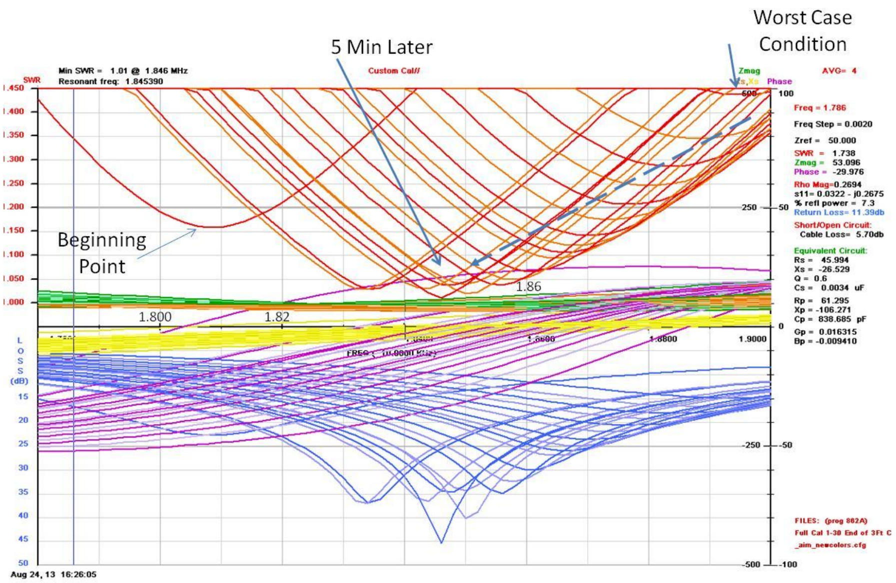
The problem first surfaced unexpectedly when operating with full power (1 KW +) for around 30 minutes in "contest mode" on 160m. The duty cycle for transmit is quite high in this scenario. Over the past year the onset of the problem has become much quicker, often taking only 2-3 minutes to appear. The VSWR meter will suddenly begin rising very quickly. After waiting perhaps 5 minutes, one can transmit satisfactorily once again, but in relatively short order, perhaps only 1 minute, the problem will reappear. Operation at the 100 W level has always been trouble-free.

My beginning fishbone had the expected items one would first suspect: poor connectors, cold solder joints, unexpected feedback of unwanted RF back into the shack, antenna interactions, etc. Part of the initial difficulty was ensuring competent delivery of almost 1.5 KW to the base of the antenna 150 feet away without a suitably rated dummy load.

Three different coaxial runs, one entirely bypassing everything in the shack, were eventually tried with the inverted-L antenna. With the help of W∅YR I was able to determine that power was being delivered to the remotely located dummy load irrespective of what cable run was used. Solidifying this assertion was the fact that three different means of feeding the inverted-L were employed: direct pigtail (with tuner in shack), L-network, and 50 ohm unbalanced to balanced current choke. The problem persisted. The fishbone was updated with things checked off as non-contributory.

With the increased testing I noticed that before onset of the problem, the reflected power on the Alpha amplifier was 30 watts, but change in an unusual way. After transmitting 2-3 minutes, the reflected power would begin decreasing, go to zero, and then begin rising to the point that concern over the safety of my Alpha amplifier became foremost. This was a clue. It appeared the antenna could be possibly changing its resonance point. A check of the coefficient of thermal expansion for copper cladded steel immediately removed that from consideration. Also, later investigations showed the resonance point was increasing and a lengthened antenna would have decreased in its resonant frequency. The quick calculation revealed at most a length increase of 0.1 inches over 140 feet. In subsequent tests when the problem began, I incrementally increased the transmit frequency, starting at 1.8 MHz and eventually getting to 1.9 MHz where the VSWR stabilized. Another clue.

In yet another test, I reestablished the problem by continual transmission, and as quickly as possible, inserted my AIM-4170 one-port vector network analyzer. The graph below in Figure 1 is the result of this test. The beginning resonant frequency was ~ 1.825 MHz, annotated "Beginning Point", and at the peak of the anomaly, the resonant frequency was close to 1.9 MHz; a phenomenal change. Continuing to re-sweep the analyzer over the next 5 minutes showed a gradual decrease in resonant frequency back toward the beginning point, but not getting completely back to the original resonant frequency of 1.825 MHz. Another set of clues: large frequency change; apparent high degree of hysteresis, and not entirely reversible.



Considerable information had been developed; what did it all mean? First and foremost, the evidence was mounting that some type of coupling at a high current point was in play, and the conditions of this coupling were power/temperature sensitive. A high degree of coupling was indicated by the extreme pulling of the resonant frequency from 1.8 to 1.9 MHz. Something far away, loosely coupled, could not do this. The phrase "far away" must be viewed in terms of wavelengths at the frequency of use, not just linear feet.

The only thing in the near vicinity of the inverted-L was the 80m inverted Vee. I started thinking that 1.8 MHz x 2 is 3.6 MHz; close to the resonant frequency of the inverted Vee. Upon dropping both legs of the inverted Vee to ground level (feedpoint still near the top of the tower) and retesting, the anomaly occurred quicker and appeared more intensified than experienced in any other test scenario. I hypothesized that in this configuration the coupling between the vertical part of the inverted-L and the inverted Vee was greater, thus quicker onset of the anomaly. I lowered the tower.

Climbing to the 23 foot level of the tower, I took steps to disconnect the 80m inverted Vee. Upon touching the PVC pipe holding the multi-core current choke at the feedpoint, I noticed it was hot near its top. Additionally, I realized the PVC pipe was bent at an angle of approximately 20 degrees from apparently many instances of heating and cooling. This looked like this was IT ! I raised the tower back to an operational height and put a KW+ into the inverted-L. The result - a gratifyingly stable VSWR.

The current choke on the 80m antenna performed as it should. In the immediate vicinity of the 160m inverted-L, both sides of the inverted Vee were receiving a very intense electric field. One half of the inverted Vee was connected to the inner coax conductor, while the other half of the antenna was connected to the shield of the coax. The high current from the 160m inverted L entered the 80m current choke on the outside of the coaxial shield and was attenuated, as expected, by the ferrite cores. The ferrite cores could not handle the strength and duration of the 160m transmissions.

Interestingly, in one of my earlier tests I disconnected all cables on the tower at the 23 foot level where the feedlines transition from heliax to RG-213. This made no apparent difference in the problem presentation, even though the inverted Vee was open-circuited at this point.

The significance of the 1.9 MHz factor became much more evident at this point as well. At 1.9 MHz the degree of coupling to the 80m inverted Vee diminished. The frequency of 1.9 MHz was sufficiently removed from an integer multiple of the inverted Vee's resonant frequency that power transfer, i.e. heating of the ferrite cores, was diminished.

This result was unexpected, but in retrospect, aligns with theory. Ferrite materials are known for nonlinear behavior, changing electrical parameters with temperature, and have a potential for core saturation, all leading to unexpected results. Gene, N3EV, speculated the problem was heat related, as did I. I didn't expect the problem to be on a different antenna, cut for a different frequency, 65 ft above the feedpoint.

In retrospect, the tremendous shift in antenna resonant frequency and the large time hysteresis were the primary indicators of ferrite involvement. And like most problems, the solution seems straight forward and easy to understand once it is explained.