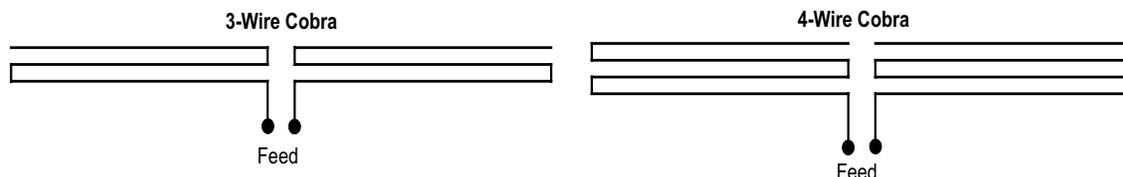


The Mysterious Cobra

By Rick Littlefield - K1BQT

We've all heard quite a bit lately about a new antenna called the cobra. Thanks to Joe, K1JEK, and several others, it has been gaining popularity in these parts as an alternative to the venerable G5RV. The original design (see the Saddleback web site) was first published by Ray Cook, W4JOH in 73 Magazine. Cook provided construction details and outlined the antenna's evolution, starting with an earlier antenna called the "rattlesnake". Unfortunately, Ray never really explained the theory of operation behind his creation. Whenever an antenna goes unexplained for very long, it tends to acquire attributes that defy the laws of Physics. Hopefully, this article will remove any cloak of mystery surrounding the cobra by providing a clear view of how it actually works.

To fill in a few blanks for anyone unfamiliar with the cobra, it is a multi-band wire-dipole using multi-conductor cable on each leg. In practice, each leg uses three (or more) conductors interconnected for linear loading. These multiple runs of wire add resonant responses (yes, that's plural) up to one octave below the antenna's primary half-wave operating



frequency:

Ray Cook used 140 feet of Romex 3-wire power cable to make his original cobra. It was quite heavy to support, so some newer versions have emerged using ribbon-style rotor cable to reduce weight and promote easier handling (K1JEK and I came up a version called the "Cobra Ultralite"). This antenna is fed with 100 feet of low-loss 450-Ohm ladder line, and when you match it up with a tuner, it will deliver wide-ranging frequency coverage.

In most aspects, the cobra functions like a traditional single-wire doublet. It is cut for a fundamental resonant frequency (generally 80 Meters), but when used with a tuner, will radiate efficiently on harmonically and many non-harmonically related segments of the HF spectrum. What makes it really different is its unique use of linear loading to expand low-end frequency coverage below its primary resonance.

Generally, linear loading uses moderate conductor spacing with conductors separated in air. The cobra is different because it uses very closely spaced conductors separated by the plastic insulation in multi-conductor wire. This insulating material has a much higher dielectric constant than air, which couples the wires more closely together. As a result of this coupling, on the antenna's "primary" band, each dipole leg acts like a single $\frac{1}{2}$ -wavelength piece of wire--even though it may have three or four times that amount of wire running back and forth. At lower frequencies, a significant change takes place where each parallel pass of wire adds a sub-band resonant response. In mathematical terms, an element constructed with N wires yields N-1 sub-band responses. Thus, a three-wire cobra has two resonant responses below the antenna's fundamental frequency, and a four-wire cobra has three. These sub-band responses aren't related to the fundamental frequency or to each other. Instead, they are a product of the amount of loading provided by each added pass of wire.

In order to build a cobra for a specific set of frequencies, we need equations that will predict the primary and sub-resonant responses. To write these for close-spaced multi-conductor cables, I built a series of test antennas under

controlled conditions and measured their performance using an analyzer. The equations to compute resonant lengths in feet are shown below:

1. *Primary Resonant Length* = 493 / Frequency in MHz
2. *First Sub-band Resonant Length* = 398 / Frequency in MHz
3. *Second Sub-band Resonant Length* = 285 / Frequency in MHz

Using these simple equations, suppose you wish to build a “shorty” 3-wire cobra with its sub-2 response on 3.9 MHz to support 75-meter operation:

$$\text{Antenna Length} = \frac{285}{3.9} = 73 \text{ feet}$$

With this length in hand, you can use the following formulas to calculate where the other resonant responses will occur:

1. *Frequency of Primary Resonance* = 493 / Length in Feet
2. *Frequency of First Sub-band Response* = 398 / Length in Feet
3. *Frequency of Second Sub-band Response* = 285 / Length in Feet

For the 73-foot shorty cobra, the other responses are at:

$$\text{Primary Response} = \frac{493}{73 \text{ feet}} = 6.75 \text{ MHz}$$

$$\text{Sub-Response 1} = \frac{398}{73 \text{ feet}} = 5.45 \text{ MHz}$$

These frequencies aren't too far from 40 and 60 meters, so with a little help from a tuner, this particular antenna might deliver respectable performance on 60 Meters at the Sub-1 response and 40-Meters at the primary response. Thus, we have a potential design for a single multi-band dipole that works both above *and below* its resonant length. Will it actually work? The answer is yes. Will it work as well as a full-sized 60 or 75-Meter dipole? The answer is, not quite. That's because the sub-band responses come with a price. For one thing, even under “perfect” conditions, the antenna is smaller--and linear loading is generally less efficient than some other forms of lump loading due to wire losses. In addition, discrepancies between modeled data and measured data suggest substantial losses occur in the wire's plastic jacketing.

Specifically, we modeled a 10-foot “test” cobra on EZNEC with air-spacing between the wires, then compared the predicted parameters with actual measured results for an antenna we constructed using insulated multi-wire cable. We then calculated that if 100 watts were being radiated from the model antenna, only 35 Watts would be radiated from the jacketed antenna—with the remaining 65 watts dissipated as heat in the wire's insulation. This amounts to a performance penalty of 4-5 dB due to dissipation losses in the cable.

Unfortunately, that's not the entire story. As multi-conductor wire elements are made longer in order to resonate at lower operating frequencies, the conductor spacing (expressed in wavelengths) becomes closer. As a result, losses (in dB) may be expected to run higher for a 100-foot antenna made from a particular cable than a 10-foot antenna made from the same cable.

To put this prediction to the test, I built a 73-foot 3-wire cobra using identical wire to the 10-foot test antenna. When installed at 50', its measured feed-point resistance (at resonance) measured 120 Ohms—as opposed to a 26-Ohm prediction for an air-spaced version modeled on EZNEC. In terms of losses, if our 73-foot air-insulated cobra were radiating 100 Watts, our multi-conductor cable version would radiate only 22. The remaining 78 watts would be dissipated as heat, causing a 6-dB performance penalty. This data suggests the physically longer 73-foot antenna does, in fact, have somewhat more dissipation loss in the wire than its shorter counterpart operating at a higher frequency.

The ultimate reality check for the “little cobra” came when we put it up against a full-sized 120-foot dipole on 75 meters. In addition to exhibiting the dielectric losses we've discussed, we'd also expect to see an additional 2-3 dB loss

because of the normal inefficiencies inherent in an air-spaced linear-loaded radiator. To gather this data, I installed the 73-foot cobra approximately 50 feet above ground and oriented it 90-degrees off-axis from my station dipole. Crosstalk between the antennas measured over -30 dB, an indicator that minimal interaction was taking place between them. I installed a precision step attenuator in the dipole's feedline to measure "real" differences in received signal strength (most S-meters are notoriously inaccurate). I used a two-position coax switch to toggle rapidly between antennas.

The performance penalty between the two antennas was represented by the amount of attenuation required to equalize signal readings between the two. The average difference over a sample of 30 trials calculated out to 9.8 dB. Significant deviations from the 9.8 dB norm were noted for some entries, possibly a consequence of the off-axis positioning of the two antennas. Also, the ground system under my dipole was somewhat better than the ground in the area occupied by the cobra. Thus, this was a pretty harsh test.

Despite this difference, the little cobra did "work" in that I made numerous two-way SSB contacts with other stations on 3936 and other nearby frequencies. The performance difference proved significant only under poor band conditions. I also ran a 1-kW carrier into it for 30-seconds without causing any damage from heat dissipation.

For the serious 75-meter operator limited by restricted space, a more efficient single-band short dipole of comparable length could be constructed using lump loading. However, for the casual operator, the 73-foot cobra design successfully adds two low-frequency bands to the antenna's span of coverage that would be unavailable from other traditional multi-band designs such as the G5RV.

So far, I've only focused on the sub-2 response, the antenna's least efficient operating mode. On the primary band, most users report no difference in signal strengths after substituting a cobra for a single-wire dipole cut for the same band. Being a skeptic, I conducted one additional experiment to check the believability of such claims by building a 10-foot test dipole using #18 copper wire. The feed-point resistance for this antenna measured 60 Ohms. Comparing this resistance to the cobra's three-wire resistance of 84 Ohms, I calculated a performance penalty slightly over 1-dB for the cobra--a difference unlikely to be noticed by anyone on the air. Moreover, this margin is probably even less for a longer antenna. Here, increased coupling between conductors should further solidify the multi-wire element's ability to function like a single conductor—causing it to perform more efficiently. Note that this effect is exactly the opposite of what happens to efficiency in the sub-resonant modes.

I didn't run any comparative tests at the antenna's first sub-resonant operating mode or at its natural harmonic frequencies. However, impedance data suggested that the sub-1 mode delivers better efficiency than the sub-2 mode. Also, the tests conducted at the primary operating frequency suggested that the antenna's harmonic and non-resonant operating performance probably mirror that of a single wire.

To summarize, from a technical standpoint, the cobra is an interesting antenna that appears to behave much like a multi-band doublet, but with the added coverage of two sub-bands. Clearly, its performance isn't magical. If you have the 140-foot version, you can expect to see reduced efficiency on 160 Meters over a 240-foot dipole installed at the same height. The good news is, for 75 Meters and up, you'll see virtually no difference in performance due to element losses.

Recapping my technical findings, which were gathered for a longer and more in-depth technical article, the electrical behavior of the cobra's linear-loaded element appears to be altered significantly by close conductor spacing and by the high dissipation factor presented by the wire's insulating medium. These features cause the radiating element to exhibit the following unique characteristics:

1. In primary mode, the multi-wire element acts as a single coherent conductor.
2. In sub-resonant modes, N conductors yield N-1 sub-band responses.
3. Sub-resonant responses are harmonically unrelated to the primary response.
4. Primary and sub-band response frequencies may be calculated predictably.
5. Sub-band efficiency is degraded by increased dissipation losses.
6. Primary-mode efficiency is enhanced by increased dissipation losses.
7. Dissipation losses increase rapidly as more element wires are added.
8. For any given cable, dissipation losses increase with physical wire length.

As a postscript, when Joe, K1JEK, tested a 73-foot “shorty” cobra at his QTH built with ladder line and connected through an ATU, he found that it tuned up and worked well on all bands from 80 through 10 meters. If you live on a small lot, the shorty might represent a good solution for getting on HF!