Loading Coils





# Current distribution in the Antenna Loading Coils.

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A recent article on eHam.net by Alan Applegate, K0BG "In Search of 'The Perfect Mobile Antenna'" on Aug. 5, 2003 and posted comments, created some controversy and heated exchange between myself and the "well respected engineer" (according to Aaron, NN6O) Tom Rauch, W8JI. This article had some flaws and was far from approaching "perfect" mobile antenna. To which W8JI stated:

*"By using a flawed and seriously over-simplified model, the results are totally misleading when applied to conventional antennas. Repeating misleading information in article after article does NOT make it correct. It certainly does not make our community more skilled or better informed about how things work."*

and

*"While I appreciate all your (K0BG) efforts, it is important that readers and writers fully understand why and how something works before reaching conclusions. Otherwise this all just wastes bandwidth, and people learn incorrect information. The goal of E-Ham and Internet should be to INCREASE technical skills through mass peer review and learning, not to repeat misinformation. "*

In view of the above and in order to *"INCREASE technical skills through mass peer review and learning"* I have summarized in my posting the most important items contributing to high efficiency of mobile or shortened antennas. W8JI commented that I was wrong about the current distribution in the antenna loading coils, where I stated:

*"4. Loading coils. Should be mounted as high as possible in the antenna mast to increase the current radiating portion of the whip. Wire or tubing should be rated to carry the power without melting the coil. Q of the coil is not that important, coil in this situation is the part of the radiating element, most of the current is at the base of the coil and surprisingly Q or form factor is not THAT important as measured and verified experimentally by W9UCW. Loading coils at the base or autotuners are the worst. Bugcatchers, single coils with no shorting, spider mounts for multiple coils are very efficient."*

To which W8JI replied:

*"The idea current is high in only the start of a coil is not correct.
Model an antenna with EZnec, and look at the load. Model a coil in any software, and look at current. Read any textbook, even beginner's textbooks, and see what they say. Measure a real antenna yourself!
......*

*You are like to call names, insult people, and argue rather than take the time to learn basic electronics. This is in any book, including the ARRL Handbook. If you look at HOW an inductor works, the current flowing in one terminal ALWAYS equals the current flowing out the other terminal. "*

(The rest of the exchange can be seen at eHam.net following the K0BG article at http://www.eham.net/articles/5998)

This was quite an accusation and a challenge to reality and my knowledge. This was not the first time that W8JI "challenged" me and was proved wrong. Knowing what was the reality (uneven current distribution, coil gets hotter at the bottom) and what Barry Boothe, W9UCW measured, I was curious what was the source of W8JI misinformation. I ordered 19th edition of *ARRL Antenna Book* and followed chain of references that led to information on page 16-7 and Fig. 9 and 10.

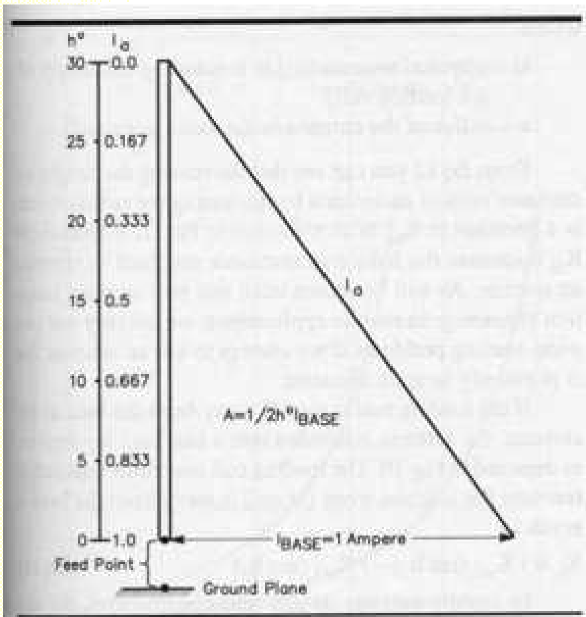



Fig 9—Relative current distribution on a base-loaded vertical antenna of height H = 30 electrical degrees (linearized). The base loading coil is not shown here.

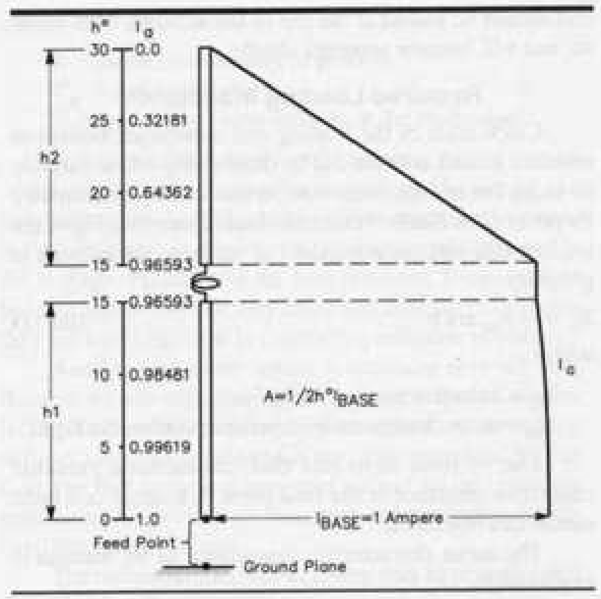



Fig 10—Relative current distribution on a center-loaded antenna with base and top sections each equal to 15 electrical degrees in length. The cross-hatched area shows the current distribution that would exist in the top 15° of a 90°-high vertical fed with 1 ampere at the base.

Looking at those two pictures, we can see that the current across the radiator was "linearized" to be a nice straight line instead of actual cosine curve. Also, Fig. 10 is missing the important cross-hatched area, the current across the coil is shown as a "nice" linear current over h2 and coil apparently has zero physical length. This passage in the Antenna Book is written by Bruce Brown, W6TWW "Optimum Design of Short Coil-Loaded High-Frequency Mobile Antennas" first published in *ARRL Antenna Compendium*, Volume 1, page 108.

Going back to that reference we can see on page 109 Fig.1 a current distribution on 1/4 wave radiator.

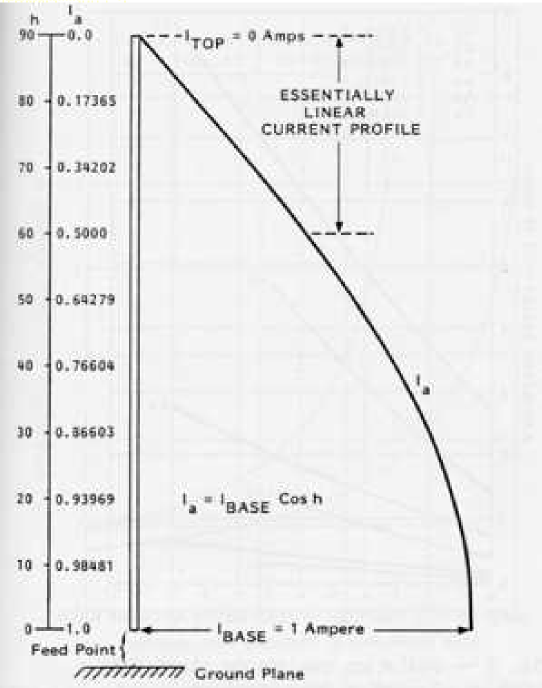



Fig. 1 — Relative current profile in a vertical antenna of height h equal to 90 electrical degrees.

This is a true representation and shows the last 30 degrees "linearized", which is OK for simplification, but it introduces an error, which could magnify in precise calculations and modeling.

This is expanded in Fig. 2,

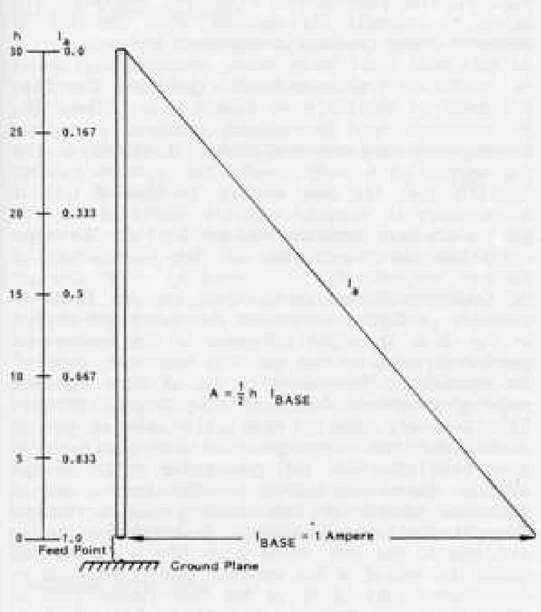



Fig. 2 — Relative current distribution in a base-loaded vertical antenna of height h equal to 30 electrical degrees (linearized). A base loading coil is omitted.

The base coil is omitted, which "simplifies" or distorts the picture of real current distribution in shortened radiator with base loading coil. As we will see later, if the coil was shown, 1 A current applied at the bottom, and current **measured** at the top of the coil, authors would have seen the drop across the coil and current at the bottom of the radiator (top of coil) would not be 1 A, but more like shown by the shaded area in Fig. 3.

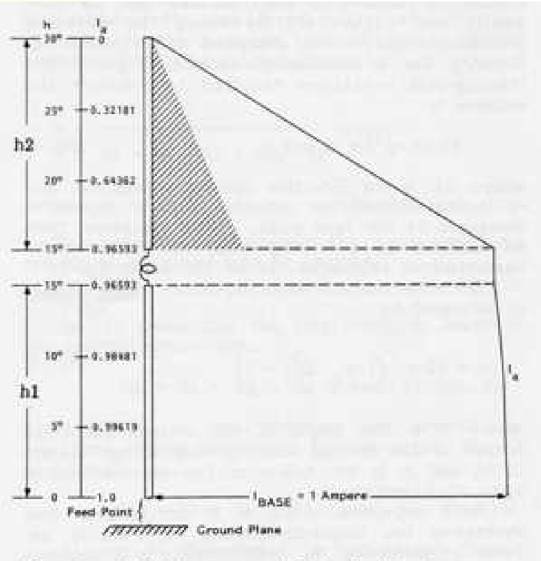



Fig. 3 -- Relative current distribution in a center-loaded antenna with base and top sections each equal to 15 electrical degrees in length. The cross-hatched area shows the current profile that would exist in the top 15° of a 90°-high vertical fed with 1 ampere at the base.

Then we see in Fig. 3 coil inserted in the middle of 30 deg. radiator. Coil has "zero" physical length and current distribution across the coil is shown as constant and as W8JI claims. The implication is that coil magically widens the area under the current curve over the top 15 deg. Here is the cross-hatched area that is missing in the ARRL Antenna Book, which is really what is happening in the coil loaded radiator. This figure implies that current across the coil is constant and actually makes short radiator work better than the "naked" one, without the coil (proportional to the areas under the current curves). In reality, the picture should show current across the coil coming from the bottom right corner of the shaded area to the top current curve at 15 deg. or bottom of the coil.

Bruce, W6TWW, states:

*"Therefore, the current exiting the top of the coil is the same as that entering the bottom of the coil. (This is true for conventional coils. However, radiation from long skinny coils allows coil current to decrease, as in helically wound antennas.) This is easily verified by installing RF ammeters immediately above and below the loading coil in a test antenna. Thus, the coil forces a much higher current into the top section than would flow in the equivalent part of a full 90-degree-high-antenna."*

So here is qualifier that in long skinny coils, as in helically wound antennas, radiation allows coil current to decrease. The problem seems to be that in one case the current decreases across the coil (helical), but in "regular" loading coil that is not allowed, which is false. (Where was the measurement, verification?)

Is this really true or is it based on a previous reference? Lets follow the trail to the referenced article (by W6TWW) in 1953 QST, p. 30 by J. Belrose, VE3BLW (now VE2CV) "Short Antennas for Mobile Operation" and we see the origin of the "constant" current across the coil and the "linearized" current distribution..

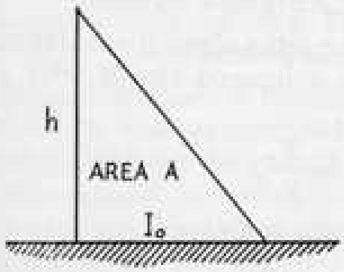



*Fig. 2* — Current distribution on a short vertical antenna.

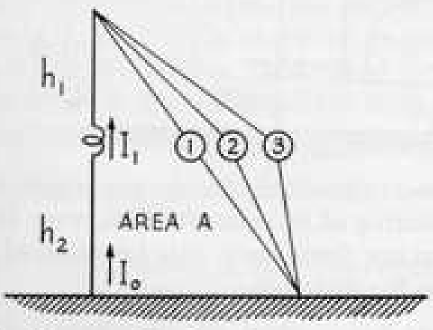



*Fig. 3* — Current distribution on a sectionalized or center-loaded antenna.

Curves with 1, 2, 3 show various current distributions from 1 for no coil, to 3 for coil that brings the antenna to resonance. Jack in his calculations assumes that the current across the coil is constant and that seems to perpetuate all the way to the latest edition of ARRL Antenna Book. So much for the "theory". What is the reality? I repeatedly asked W8JI to measure the current in typical mobile coil loaded antenna, like in Hustler 80 m resonator. His reply was that he measured thousands of coils and he found constant current. He would not reply to this one case that represents a typical situation and is the subject of this dispute.

**What is the truth?**

It all started with discussion on the TopBand Reflector (see the archives on eHam.net for May 2003) with thread "160 m Mobile Antenna Suggestions"

http://lists.contesting.com/_topband/2003-05/msg00044.html

Barry, W9UCW pointed out his findings based on real life measurements of decreasing current across the loading coils. This agreed with my "unscientific" experience, when I fried the loading coil with 600W into Hustler resonator, melting heat-shrink tubing and wire at the bottom of the coil. There was an exchange of arguments on the subject of current in the loading coils, with W8JI insisting on constant current across the coil. Unfortunately, the TopBand reflector moderator terminated W9UCW responses, so W8JI had his famous "right" last word.

**Tom, W8JI** on his web page http://www.w8ji.com/mobile_and_loaded_antenna.htm states:

*"The modeled current distribution for 1-ampere applied at the base (in 1-foot intervals) is:*

*1ft= 1.0031*
*2 ft= 1.0091*
*3ft= 1.0178*
*4ft= 1.0318*
*<Coil>*
*5ft= 1.0175*
*6ft= .97512*
*7ft= .92984*
*8ft = .89522*

*Measuring the current into and out of the loading coil with a small thermocouple RF meter, I detect no difference This is in close agreement with the model.* "

and "conclusion"...

*"Clearly there is no basis to the claim current is high only in the first few turns of an inductor, or that current tapers in relationship to "electrical degrees". The most accurate way to state the effect would be to say: "When the loading coil is short and the capacitance of the antenna beyond the coil is reasonable (in this case 3000 ohms Xc or less), there is an immeasurable reduction in current in the coil."*

First, there is a problem in his modeling with current increasing from the base towards the coil. That should be the flag telling him that 2 + 2 is not sometimes 4.04. Second, EZNEC has no provision for incorporating physical length of coil. It just considers LC parameters. Roy Lewallen, W7EL, author of EZNEC and Richard Clark, KB7QHC recommend workarounds to replace the coil with cylinder of similar size or breaking the coil to number of physical segments with appropriate inductances. W8JI "findings and measurements" hardly reflect the reality. As someone said, one measurement is better than thousands of theories. The question is, how was W8JI measuring the current, and getting more current than it was applied at the base?

**Barry, W9UCW** among other arguments and explanations wrote:

*"In our measurements, we used long and short coils and the current taper was was almost identical if the topmast capacitance was held the same. If the "make up" was above the coil, there was slightly less taper down of current, due to the larger capacitance above. It would also resonate lower in freq. It appears to us that the current decrease in the coil has most to do with the section of the quarterwave element that it effectively replaces. The actual decrease in our tests was always a little more than the decrease calculated for the "replaced" section, no matter what coil was used. I hope that answers your questions."*

*"I think your position (W8JI) is clear....that under the condx described, current reduction in a loading coil can't, won't, never did, never will happen. My position is that it always does, and I've measured it. Neither of these hypotheses will go far to satisfy the real objectives of our study."*

Barry, W9UCW was kind to provide proof in the form of some measured data and photographs showing the antenna setup, loading coil and RF ammeters installed at the top and bottom of the loading coil, which could be reversed:

***"Here are some actual measurements of current below and above loading coils.***
***92" mast, using a HI-Q coil (openwound airdux, 2 1/2"d) with small thermocouple type meters mounted on the insulated coil support. First for 40m, moving the coil in the mast from base to center to top (with hat) and reresonating.***
***Base --100ma below & 66ma above***
***Center --100ma below & 45ma above***
***Top --100ma below & 37ma above***

***Then, same test but for 30m***
***Base --100ma below & 75ma above***
***Center --100ma below & 60ma above***

***Top --100ma below & 52ma above***

***On a long, skinny 160 resonator with 25pf of top hat and whip, mounted on an 8' mast, I read 100ma below and 65ma above the coil.***

***Because of the constant claim that this must be due to the fact that the coil is so big compared to a wavelength, I measured the in and out current on a TOROIDAL loading coil used on a 20m mobile antenna. It was a 78" base mast (including spring and mount) with a 38" top whip (including 12" of alum. tubing for adjustment).***

***Below --100ma & Above --79ma***

***When I moved the coil to the top of the mast and made a horizontal "X" top hat to resonate it back on the same freq, I got***

***Below --100ma & Above --47ma***

***So, It happens even in a totally shielded loading coil with miniscule power going thru it! Kirchoff has no laws about current being the same on both ends of inductors. His current law is about one POINT in a circuit and his voltage law is about a closed loop."***

... and some significant difference W9UCW in field strength measured between the base and center loading coil:

***"The actual difference in signal strength between top and base loading of a 9' antenna is about 16 db (measured) on 75m, but Tom calculates 8db on 160. That's because he assumes the same current in the coil. Actually it's worse on 160 than 75."***

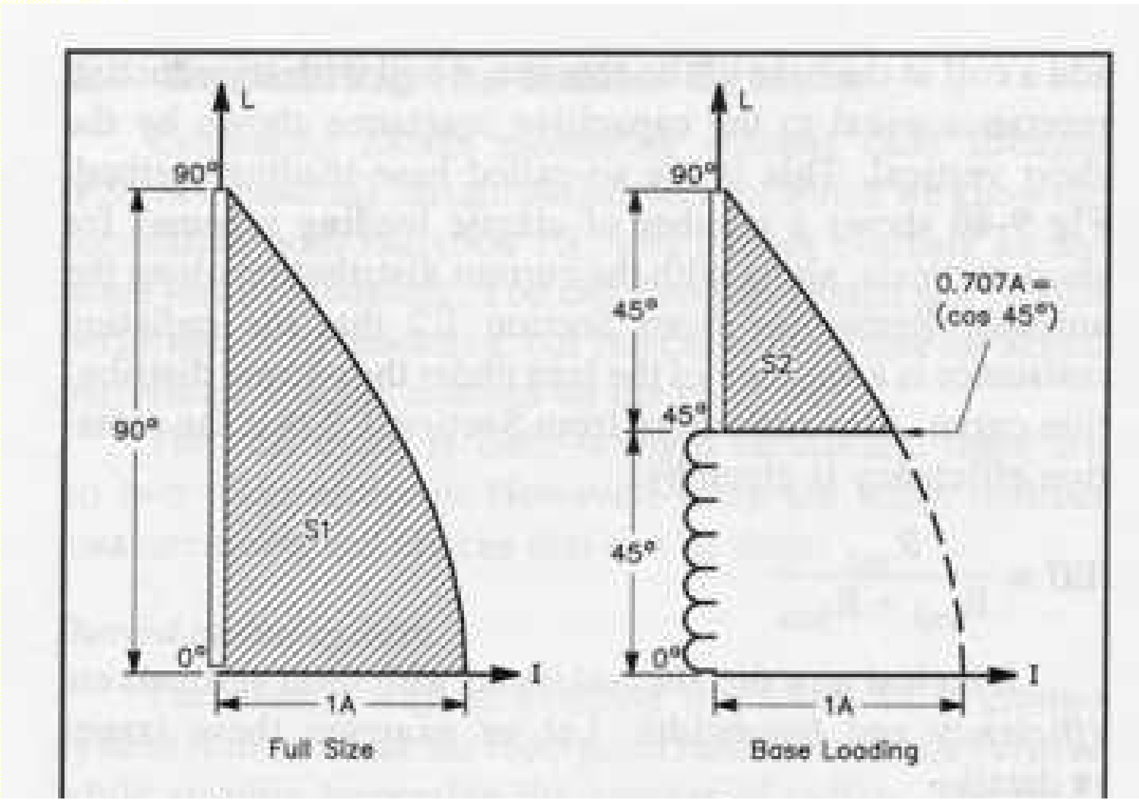
## Barry's pictures are worth a thousand words:

W9UCW's setup with radial field (60), base loaded vertical with RF thermocouple ammeters inserted at the top and bottom of the coil.

Here is the coil in center loaded radiator, 100 mA meters at both ends of the coil. The bottom one is showing full deflection (with power adjusted to) - 100 mA while at the same time the top ammeter is showing 45 mA as described above. The meters were mounted that way so that they could do a test and then just turn the coil assembly upside down and do another test to make sure results were the same and that no anomalies crept in. Results were always identical.

## The reality.

So how does the real distribution of current in loaded antennas look? The answer can be found in the John Devoldere's "Bible" - "ON4UN's Low Band DXing", 3rd Edition, on page 9-34:



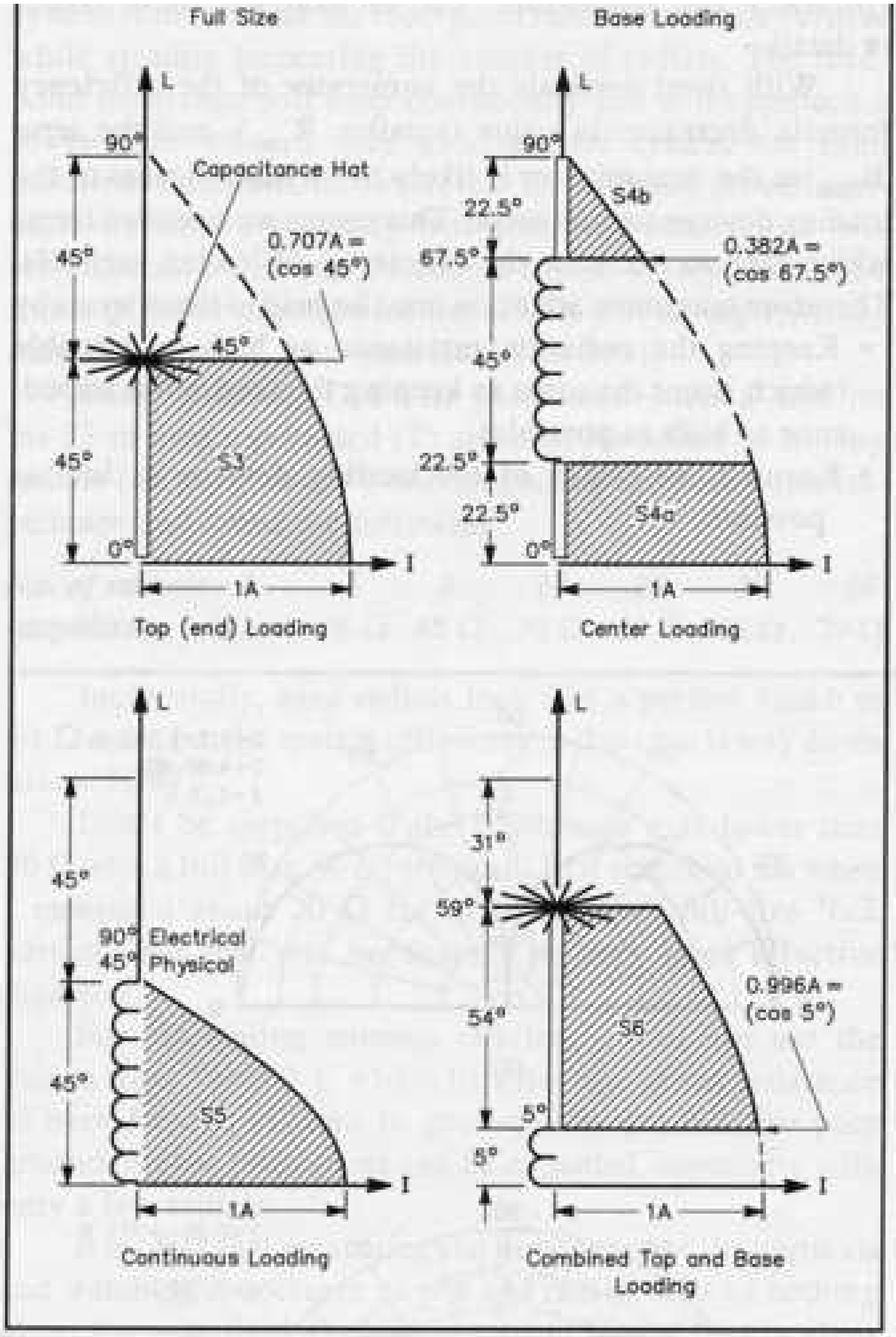



**Fig 9-40—Short loaded verticals with their current distribution. The radiation resistance is proportional to the area under the current-distribution curve. The efficiency is also proportional to the radiation resistance. See text for details.**

When I pointed out this reference to W8JI, his response was:

*"I just looked at that, and you are right. John is incorrect, and I'll bring it to his attention. Thanks for pointing that out."*

This is not the first time that W8JI is wrong. His typical modus operandi is first to attack and ridicule the opponent, then the exchange of arguments ensues. When he realizes he is wrong, rather than admitting, he clouds the issue with his "arguments". After staying quiet for a while, he then emerges, pretending to be the expert on the subject with corresponding postings on his web page, without giving credit to the originator. Normally this is called plagiarism.

The Internet is a great place to publish ideas, good and wrong. In the spirit of Tom's posting on the eHam.net's purpose, I had to react to his disinformation by presenting the facts, especially when it happened more than once.

Why is this important? Technical subjects have their laws and rules. Perpetuating wrong information doesn't serve anybody. As we can see in this example, something that was "established" 50 years ago, perpetuated through "peer reviewed" books to this day, can cause problems and wrong conclusions.

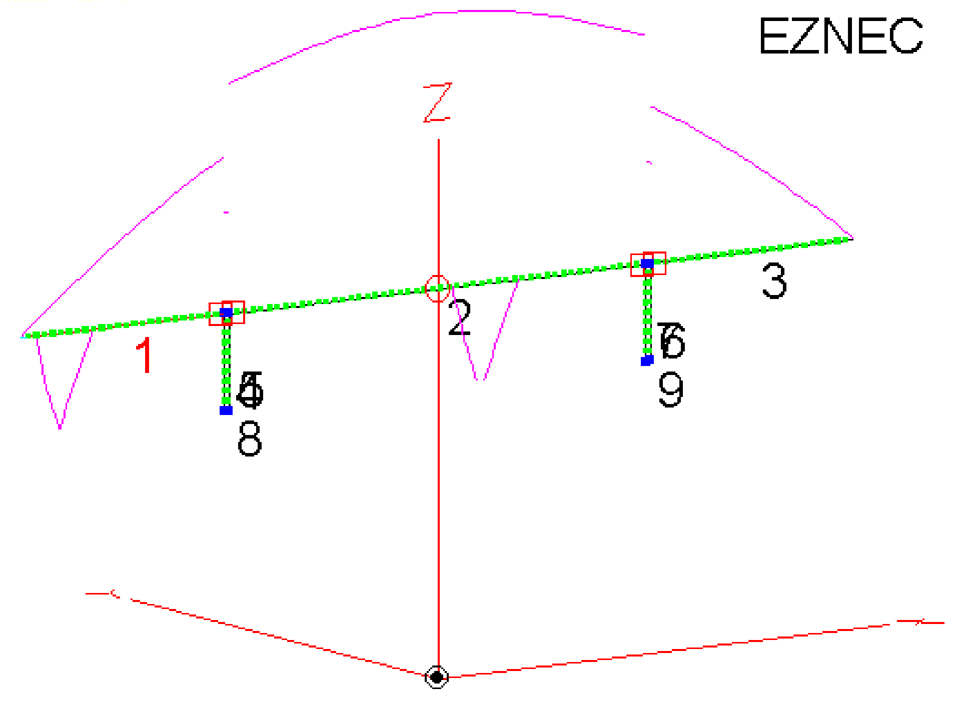
In summary:
**The current in a typical loading coil in the shortened antennas drops across the coil roughly corresponding to the segment of the radiator it replaces.**

... and that's the way it IS, *hardly W8JI's* -

*"...there is an immeasurable reduction in current in the coil."*

I hope this will help to better understand the loaded antennas, to incorporate the effect into the modeling software and to develop more efficient shortened antenna systems.

Below is the result of plotting current in the G5RV antenna using inductors in the form of loading stubs as done by W5DXP in Eznec. It can be seen that the current entering the stub is greater than current exiting the stub. When simple inductance in Eznec is inserted in place of the stubs, the current erroneously is shown as the same at the both ends of the inductor.




[Comments from the REC.RADIO.AMATEUR.ANTENNA News Group]

# Comments





**Here are some comments relating to the subject of current distribution through loading coils as rehashed on rec.radio.amateur. antennas news group:**

**Posting by Cecil, W5DXP shedding some light on the "theoretical" (Kirchoff and Ohm laws) arguments and their propriety to the case:**

*"Assume a transmission line with an SWR of 10:1. Put a series inductor in series with the transmission line. Assuming negligible losses, the forward current is the same at each end of the coil and the reflected current is the same at each end of the coil. The question is: Do the superposed currents, Ifwd+Iref, remain constant? Of course not, because of phase shifts. With a large enough coil, one could cause a current maximum point on one side of the coil and a current minimum point on the other side.*

*That same principle holds true for standing wave antennas which are antennas with (surprise!) standing waves. The current is NOT the same at each end of the coil (unless a current maximum or current minimum occurs in the middle of the coil). However, for traveling wave antennas, the current at each end of a loading coil would be close to equal.*
--
73, Cecil http://www.qsl.net/w5dxp"

**More info from Cecil, W5DXP on the subject:**

*"Yuri Blanarovich wrote:*
*> What I was looking for is to see 1. if anyone else MEASURED the current in*
*> loading coils, and what results they arrived at (and if we are wrong, then*
*> where did we go wrong). 2. If this is right than to have modeling software*
*> implement it with least error. I would like to use that for optimizing, say,*
*> loaded elements for receiving arrays on low bands, optimizing mobile antennas,*
*> loaded multielement beams, etc.*

*Hi Yuri,*
*try this out for your argument in the other group. Using EZNEC:*

*Example 1: 102' CF dipole with loading coils in the center of each arm to cause the antenna to resonate on 3.76 MHz. I get XL=j335 ohms.*

*Example 2: Replace the above loading coils with series inductive stubs hanging down. Ten foot stubs with six inch spacing between the wires is what I used. What happens to the current across that six inch gap is obvious from the current plot using EZNEC. Hint: There is a step function across that six inch gap just as there will be with a six inch coil.*

*Then ask: Why doesn't EZNEC treat these two cases the same way?*
--
73, Cecil http://www.qsl.net/w5dxp"

**and …**

"
Yuri Blanarovich wrote:
> There is too much reliance now going on modeling program results, ignoring some
> realities.

*Yuri,*
*here is a modeling result that you might like. :-) I took a 102' dipole and loaded it in the center of each leg with an inductive stub that made the dipole resonant on 3.76 MHz. I added a one ohm series 'load' to each side of the stub. Drawing one leg of the dipole, it looks like this:*

```
----------R2-+ +-R1----------FP--- ... other half
             | |
             | | inductive
             | | stub
             +-+
```

*EZNEC reports 0.85 amps through R1 and 0.57 amps through R2, a difference of 33%. If one could model the inductive loading reactance as an actual physical coil instead of a lumped single point impedance, results would be similar to the above.*

*Now here is something that might blow some minds. The inductive stub above is ten feet long. That's about 1/8WL on 20m. A 1/8WL shorted stub equals +jZ0. The results of running the above antenna on 20m is that the current through R1 is 185 degrees out of phase with the current through R2. At the time when the current through R2 is flowing toward the end of the antenna, the current through R1 is flowing toward the feedpoint. Wonder what Kirchhoff would say about that. If you replace the stub with a coil of the same reactance, not much changes.*

***Tell W8JI to stop using lumped circuit analysis when he should be using distributed circuit analysis. :-)***
--
73, Cecil http://www.qsl.net/w5dxp"

**W5DXP:**
Yuri, my latest posting sheds more light. Apparently, W8JI doesn't realize that there are two superposing currents phasor-adding together to get the net current and the phase distribution between those two current waves are opposite because they are traveling in opposite directions. This is a characteristic of standing-wave antennas.

See what happens when one tries to ignore the component waves?

Because the two currents are traveling in opposite directions, any phase delay through the coil shifts the phase of the two currents IN OPPOSITE DIRECTIONS. Thus the total relative phase shift effect through a 10 degree coil is 20 degrees.

Mark, NM5K wrote:
> Dunno...I finally got up enuff courage to wade thru a bunch of that
> myself. Both had some decent points..But....Just using my built in
> "BS" filter only, which  rarely seems to fails me,  and ignoring all
> other influences, I still have to side with Tom. I still think the
> current is fairly constant.

W5DXP:
The key to understanding is to realize that the net current is the phasor sum of the forward current and reflected current (on a standing-wave antenna). Assume a 10 degree phase delay through the coil on the frequency of operation. Ifwd-in and Iref-out are on the same side of the coil. Ifwd-out and Iref-out are on the other side of the coil.

```
           Ifwd-in-->    coil    Ifwd-out-->
----------------------////////////------------------------
          <--Iref-out           <--Iref-in
```

Assume that |Ifwd-in| = |Ifwd-out| which satisfies Kirchhoff

Assume that |Iref-in| = |Iref-out| which satisfies Kirchhoff

Ifwd-in + Iref-out = net current on left side of the coil

Ifwd-out + Iref-in = net current on right side of the coil

Ifwd-out lags Ifwd-in by 10 degrees

Iref-out lags Iref-in by 10 degrees (Iref-in leads Iref-out)

Now let's assume that Ifwd-in and Iref-out are in phase. So current on the left side of the coil equals Ifwd-in at zero degrees plus Iref-out at zero degrees which is a current maximum point.

Ask yourself: Can we have a current maximum point on both sides of the coil? I trust that answer is obvious.

Ifwd-out lags Ifwd-in by 10 degrees. Iref-in leads Iref-out by 10 degrees. So current on the right side of the coil equals Ifwd-out at -10 degrees plus Iref-in at +10 degrees, NOT a current maximum point.

Therefore, in this example, net current on the left side of the coil
cannot possibly be equal to net current on the right side of the coil.
--
73, Cecil   http://www.qsl.net/w5dxp

**and summarized by W4JLE:**

*If we feed an antenna at the current point, the current decreases as the voltage increases along the antenna element from feed point to end..*

*That being said, a coil replacing a segment of an antenna (in order to physically shorten it) will exhibit the same properties (relating to currents) as the segment it replaced.*

## Posted By W5DXP:

(> W8JI comments)
> Cecil,
>
> Apparently you have never taken time to read what I actually said,
> and what Barry Booth W9UCW and Yuri said.

I came in late on the thread and have not read all the postings except for yours. Please don't assume that I agree with Barry and Yuri 100%. Here is one of your assertions picked at random:

> In a normal mobile or home antenna with even a somewhat reasonable
> loading coil design, the current is immeasurably different at each end.

Besides your one special case toroidal coil example, every measured configuration has the currents *measurably different* at each end. Measure the delay through your toroidal coil and I will calculate that difference for you since you are unable to measure it. There is no such thing as a real-world coil with a zero propagation delay! Your above statement is false as are a number of your other statements. I hate to waste bandwidth quoting your false statements, but here are some of them:

> ... compared to
> antennas with proper inductors like the Bugcatcher, which has

> almost perfectly equal currents at each end.

A Bugcatcher is not a toroidal coil. The magnitude and/or phase
of the two currents is NOT "almost perfectly equal".

> In a well-designed system, the current is almost perfectly uniform.

All "well-designed systems" use toroidal coils? :-)

> 2.) In a normal mobile or home antenna with even a somewhat
reasonable
> loading coil design, the current is immeasurably different at each end.
> For all practical purposes, it is identical because a common properly
> working current meter would never resolve the difference.

Your "common properly working current meter" proves it is measurably
different except for one special case toroidal coil.

> It (current) is exactly equal in a two terminal component, and in a
> typical reasonably mounted and constructed loading coil there is only
> a modest current reduction at best.

The 180 degree phase-reversing coil in Kraus' phased array is a
two terminal component which is small compared to the 1.5WL of
the wire in the antenna. The currents have opposite phases. Is
Kraus wrong?

> Model an antenna with EZnec, and look at the load.

Note: EZNEC makes an assumption about lumped inductive loads that is
not valid for real-world coils. EZNEC cannot be used to prove anything
about real-world coils. It seems obvious that you didn't know that at
the time you posted the above.

> The rule is this:
> Coil current is essentially equal at both ends, as long as the coil
> is not long compared to the length of the antenna.
>
> THE VOLTAGE can be (and is) different on each end of the inductor,
> NOT the current.
>
> Unless the coil has
> considerable length compared to the antenna length, it has the
> essentially the same current in one terminal as out the other.
>
> The CORRECT current distribution is shown in the ARRL Antenna
> Handbook in 16-6 figure 9 of the 18th Edition.

Note that an earlier figure (Fig 7 in the 15th edition) contradicts
the above. There is always a current step-function across a real-
world loading coil used in a physically short 1/4WL antenna. Your
quoted figure is the one that is wrong and needs to be corrected.

> Displacement current over the length of a small fractional wavelength

> loading coil that is not operated near self-resonance is minimal to
> the point of being immeasurable.

You *measured* it on *every* configuration except the toroidal coil.
Roy even *measured* it on a toroidal coil.

> When it (inductor) is a series circuit, the voltage increases and
> current remains constant.

This is what you posted and apparently once believed. Your own measurements
prove this to be a false statement. The current remaining constant in both
magnitude and phase violates the laws of physics.

> Unlike some have claimed, Eznec and Spice models MUST calculate currents
> accurately or the results are grossly wrong.

As has been proven, EZNEC does not calculate currents accurately.
I have EZNEC files to prove that if anyone wants them. One simply
cannot model a phase-reversing coil using EZNEC's lumped inductance.

> The current flowing in must equal sum of currents out.

Nope, in a phase-reversing coil, the current flowing in can be
one amp into each end (zero current flowing out). This was your
original basic mistake - using lumped circuit theory on a distributed
network problem.

> In a properly designed system with the coil reasonably far from self-resonance,
> the current would be essentially equal at both ends unless the coil was very
> long compared to antenna length.

In your measurements, your coils are NOT "very long" compared to the
antenna length. A Bugcatcher coil is NOT "very long" compared to the
antenna length.

> I never said the current couldn't be different, I simply said it has
> nothing to do with the "electrical degrees" as Yuri and you propose.

Apparently, you have never taken time to read what I actually said.
I said every real-world coil has a delay through it and that delay
affects the superposition of the forward and reflected currents. On
my web page, I give an example of a coil with a 45 degree delay. It
seems obvious to me that delay can be almost anything except zero.
Believing that the delay through a coil can be zero violates the
laws of physics. Please don't confuse what Yuri has said with what
I have said.

> Despite the fact the electrical length "replaced" by the loading coil is

> about 60 degrees, there was only about 3 percent difference in current going
> into the coil and current coming out in Roy's measurements and NONE in mine
> with a toroid.

I gave you the formula for calculating the degrees occupied by the coil. ArcCos(0.97) is 14 degrees. I didn't say it would be 60 degrees. I said the degrees occupied by the coil can be estimated using ArcCos(Iout/Iin). Incidentally, if the magnitude and phase of the current into and the current out of your toroid are equal, your toroid violates the laws of physics.

If there is no difference in current going into and out of your coil, then there is zero delay through the coil. But there is a delay through *every* real-world coil. Whatever that delay is, it affects the sum of the forward and reflected currents. If your feedpoint impedance is slightly inductive, a current maximum point exists inside the toroid and could explain your unusual measurements. In that case, the magnitude
of the currents could be equal but the phases would be opposite.

> With a conventional small coil, Roy and I both measured about the same taper.
> Still only a few percent.

You said: "... the current is immeasurably different at each end." Now you
admit that you and Roy MEASURED it. Both statements cannot be true.

> Frankly like Roy I am a little embarrassed to have to argue something as simple
> as how an inductor works.

Frankly, I am embarrassed that a well educated and otherwise knowledgable
engineer once believed the following statement: "In a normal mobile or home antenna
with even a somewhat reasonable loading coil design, the current is immeasurably
different at each end.", and now won't even admit that statement/belief was
false even though the currents have been proven to be measurable. The discussion
had to be diverted from a normal bugcatcher mobile loading coil to a hardly-ever-
used-for-mobile toroidal coil to try to save face.

In short, for every real-world coil, there is a difference in the magnitude and/or phase of the net current-in compared to the net current-out. To maintain that the current-in is ever equal in magnitude and phase to the current-out in a real-world Bugcatcher coil is simply wrong.
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73, Cecil http://www.qsl.net/w5dxp