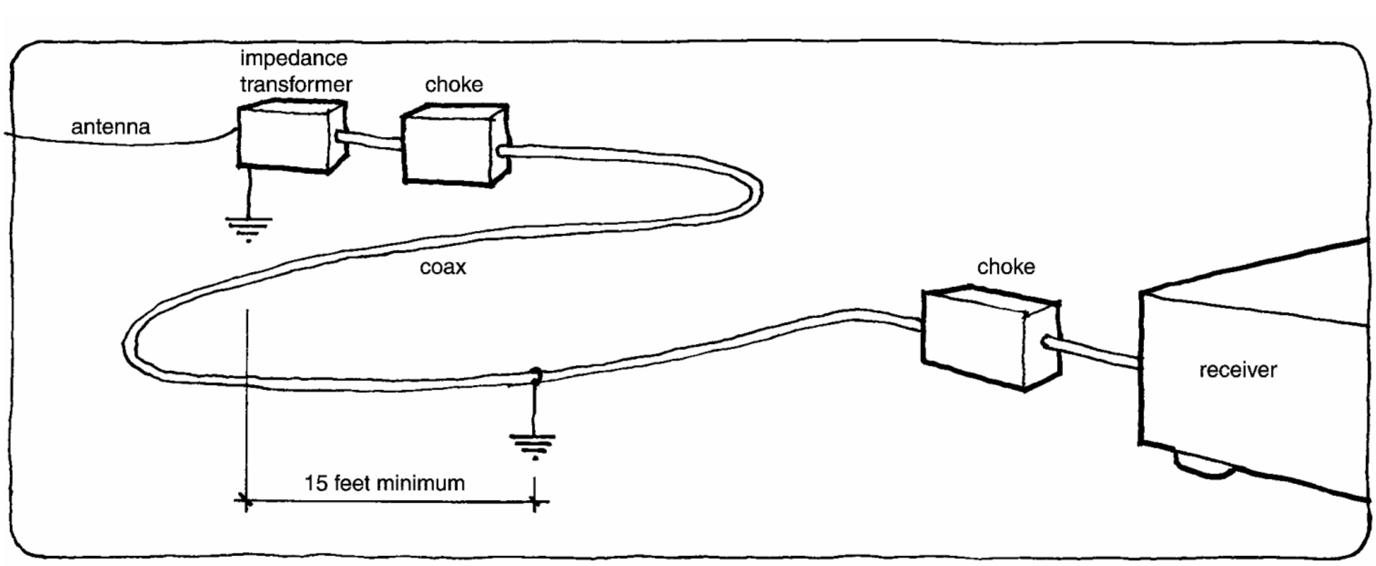
Is Your Coaxial Lead-In Actually an Antenna??

John H. Bryant with Bill Bowers, February 2001
with VERY IMPORTANT UPDATERS: May and November 2003

Like most SWBC and MW DXers, I've used coax cable "lead-ins" since such cable became commonly available in the 1960s. My main purpose was to shield the actual signal carrying conductor from as much noise as possible – mostly noise generated in and around my own home or that of neighbors'. Because my shack seems to always end up on the second floor, I've been far too informal about providing either RF grounds for the shield of the coax or electrical grounds for the equipment. In recent years, I've used only Beverage antennas for SWBC or MW DXing. I've sometimes worried that my lead-ins were not "sanitary" enough, that I was sacrificing some of the antennas' directivity through my slovenly behavior…. But, hey! There were still very clear directional distinctions between my three or four semi-permanent Beverages, so why worry??? How much directivity could I be losing, anyway? It wasn't an idle worry because the distance to the K9AY is about 100' and the distance from the shack to the confluence of the Beverages is over 250'.

Then I went DXing in the Pacific Northwest with Don Nelson of Beaverton, OR, three years ago. When I inspected his beverages, I found that he was using a special configuration of RF chokes on the braid of the coax with a separate ground for the coax braid. He related that he had just read about this approach to sanitizing lead-ins in the 3rd Edition of John Devoldere's *Low Band DXing* and had tried it on his last DXpedition. There, he had been able to do one A-B experiment where, without Devoldere's choke arrangement, all he heard on 5025 kHz. was the semi-local pest R. Rebelde. With the chokes in the lead-in, he was able to log the Australian on that frequency quite handily. Without the chokes, it seemed that energy from powerhouse Rebelde was either leaking into the coax by capacitive coupling between the outer braid and the central conductor, or that the somewhat lossy local ground wasn't working well enough to keep the lead-in "sanitary."

Well, I went out and bought the 3rd Edition in a big hurry. Over 50% of the book is oriented to reception, so this Low Band "bible" is really useful to Tropical Band and MW DXers like me, too. Midway through Chapter 7,"Special Receiving Antennas," John wrote a section titled "Is Your Coaxial Cable a 'Snake' Antenna?" where he discussed the various causes of unwanted signals getting to the center conductor of cable and proposed the voltage-divider choke and ground arrangement that Don was using. (cf. Devoldere pp. 7-18 to 7-21)



TYPICAL CHOKE INSTALLATION

John used two chokes, one near the antenna/lead-in juncture and the other near the receiver, each made from 100 ferrite beads strung on the outside of the coax. The ferrite beads are each the size of a thick, large wedding band. The 100 bead chokes each provided the desired 1500 ohms of impedance at his frequency of interest, 1800 kHz. The impedance increases from there as frequency increases and decreases with lower frequency, proportionally, as well. The lead-in braid is grounded somewhere between the two chokes. I might note that John's illustration of the placement of the "receiver choke" in the referenced section is open to several interpretations. The placement shown in my illustration above is what was intended.

The design of the choke that John uses, employing 100 ferrite beads, makes sense for someone interested in DXing only frequencies of 1800 kHz. and above. However, since I wanted to be able to DX down to the lower end of the LW broadcast band, say 150 kHz. Using John's design, I would need several hundred beads for each choke! Amidon currently sells the beads for just under 40 cents each, in one-dozen lots, or for 14 cents each if you purchase them in 1000 bead lots. Obviously, for LW and MW DXing, the choke design based on ferrite beads would be both very large and very expensive. Luckily, there is a rather obvious alternative design, also covered in *Low Band*: a choke wound from RG-174 mini-coax on a ferrite toroid core. The ferrite toroids cost less than $4.00 each and a 100' reel of RG-174 is less than $15. This was a much less expensive alternative for my needs.

At this point, I had just three questions: "Does my coax act like a 'Snake'"? "Are the choke design formulae to be trusted in this application?" and "What is the insertion loss of these chokes on the center lead-in itself?"

Snake Hunting

The 250-foot run of coax to the apex of my half-wagon wheel of Beverages is particularly vulnerable to picking up unwanted signals. It runs through an unused pasture that sports waist high grass for half the year. Several years ago, I noticed that field rats had begun to feast on the covering of the coax, then lying on the ground. I decided to elevate the coax about three feet out of harms way rather than bury it, a configuration that invites picking up unwanted signals (and noise) on the coax. John Devoldere suggests testing for unwanted signal pick-up by leaving all grounds in place, removing the matching transformer from the far end of the coax and connecting the shield and the center conductor together at the far end. What you then hear at the receiver is the unwanted signal pick-up of your lead-in and grounding system. Checking this on the broadcast band is especially encouraged. I decided to run a test that seemed even more relevant to me: I simply removed the beverage antenna from the matching transformer and left the matching transformer and grounds in place, as well.

This is embarrassing, but I must report that my 250-foot coax lead-in to the beverages flunked this test, badly! On MW, I could make out programming on almost every channel, though most of the signals were weak, around S-2 or below. The three 50 kW. stations in the state were about S-6. On the lower half of MW, I was also picking up a lot of 60-cycle hash. On long wave, the 60-cycle hash was even worse, of course. On the Tropical Bands, I only heard a few of the strongest signals, but on the 6 MHz. SWBC band, I could hear at least 20 signals. On all frequencies, I could hear lightning crashes. What does this all mean: at least on MW, the directional characteristics of my beverages were being compromised, more so on the channels with stronger semi-local stations. On all bands, the signal-to-noise ratio was being compromised rather badly, with the lead-ins picking up a good deal of 60-cycle hash and boosting the levels of lightning crashes. Poo!

I did not test my 80 to 100 foot lead-ins to the K9AY antenna because it is already packed away for transport to our summer place in the NW. I presume that the situation with it was not quite so bad, since the lead-ins were shorter and mostly lay directly on the ground.

Clearly, it was long past time to get serious about sanitizing my coax!

Choke Design and Testing

The design of ferrite toroid-based RF chokes of the type needed for this application is fairly straightforward. For my own DXing interests, it seemed to make sense to provide 1500 ohms of impedance (the minimum that Devoldere recommended) at 150 kHz. This would give me sanitary lead-ins from below the bottom of the long wave broadcast band upwards in frequency until the choke "ran out of legs" well above the Tropical Bands.

Before you can determine the number of turns needed for a particular choke design, you have to determine the inductance necessary to create the desired 1500 ohms of impedance at 150 kHz.

The formula for the inductance needed is:

$$\mathbf{X = 2\pi \mathit{f} L}$$

where **X=**Reactance in ohms ***f*=**Frequency in kilohertz **L=** Inductance in millihenries
solving for $\mathbf{L = X/2\pi \mathit{f}}$ = 1500/6.28 x 150 = 1.6 millihenries

So, the inductance needed to produce 1500 ohms impedance at 150 kHz. is **1.6 millihenries**.

From there, you must turn to the technical data sheet provided by the ferrite toroid manufacturer, in this case, Amidon. Their data indicates that the number of turns through the toroid necessary to produce the proper impedance is:

$$\mathbf{N} = 1000\sqrt{\mathbf{L / A_L}}$$

> In narrative, this formula should be read: Number of turns required (**N**) is equal to 1000 times the **square root** (√) of the Inductance (**L**) divided by the constant $\mathbf{A_L}$.

I decided to use Type 75 ferrite material (the one recommended by Devoldere, also) and selected the size FT-140. The toroid is 1.4 inches in diameter, with the toroid wall being about .5 inches wide by .25 inches thick. The $\mathbf{A_L}$ figure for this toroid in Type 75 material is **6736**. This figure is found in a table contained in the Amidon technical sheet, as well. The turns count comes out to be 16:

$$\mathbf{N = 1000\sqrt{1.6/6736} = 15.4 \text{ turns, use 16turns}}$$

After fabricating a number of these, I'm happy to report that 16 or 17 turns is about as much RG-174 coax as you can close wind in a single layer on the FT-140 toroid. It makes a neat installation.

Here are three designs using popular toroids:

Toroid	**Turns**
FT-140-75	16
FT-114-75	22 (Not sure that this is physically possible with RG-174 coax)
FT-114-43	52 (Physically impossible with RG-174 coax)

Testing Impedance

Testing was done at Bill Bowers' workbench, using a H-P Variable Frequency Impedance Bridge for impedance measurements and a laboratory-grade signal generator and voltmeter to measure insertion loss of the chokes.

FT-140-75 with 19 turns of RG-174

Bill had designed this choke to serve his interests in long wave DXing. Therefore the lowest frequency, used for the design, was 100 kHz. The results:

Frequency	Impedance
100 kHz	1500 ohms @ +89 deg.
250 kHz	4200 ohms @ +80 deg.
500 kHz	10,000 ohms @ + 60 deg.
1000 kHz	15,800 ohms
2000 kHz	6700 ohms
5000 kHz	4100 ohms

Comment:

Bill was able to perform impedance tests above the frequency range (500 kHz. and below) of his HP Impedance Bridge on this core in a less sophisticated but accurate way. The impedance of the choke peaking near 1000 kHz (in this case) and then slowly decreasing is likely due to the fact that permeability of type 75 material starts to fall off at higher frequencies. Inductance (and inductive reactance) is dependent upon permeability, so there is less impedance at higher frequencies. In addition, there appears to be self resonance effects due to inter-winding capacitance in parallel with the inductance of the winding (see the negative phase angle at 500 kHz with the FT140-75 using 32 turns below), but this has not yet been completely investigated. Note: This design would be very satisfactory for DXers who listen to LF broadcasters, MW and tropical SWBC bands.

FT-140-75 with 16 turns of RG-174

We then tested the same toroid with 16 turns as in the design example above. The results were very similar to Bill's 19-turn choke.

FT-140-75 with approximately 32 turns of RG-174

Finally, we tested an FT-140 with as many turns as it is possible to put through the center of the toroid, approximately 32. The results:

Freq	Impedance
100 kHz	4000 ohms @ +90 deg.
250 kHz	20,000 ohms @ +65 deg.
500 kHz	17,000 ohms @ -60 deg.

Z(maximum) was at 350 kHz where z=40,000 ohms

Comment:

An early document from Amidon Associates entitled "Using Ferrite Materials for R.F.I. Problems" states that "Although the increased number of turns will increase the impedance at the lower frequencies, the capacitance build-up due to the increased number of turns will cause the coil to become less effective at the very high frequencies." In this case, impedance would continue downwards with frequency, but should still be far above the required 1500 ohms at even 10 MHz.

Insertion Loss

Bill and I checked the insertion loss of each of these chokes at 1 MHz. and 5 MHz. Happily, the insertion loss of each of them, along with two bead chokes that we checked, fell in the 0.2 to 0.3 dB range, probably attributable to the BNC connectors on the coaxial cable. Thus, the insertion loss of these devices may be ignored.

Are the Snakes Out of the Antenna?

Well, mostly! With the same set-up of lead-ins but with the two chokes and a new shield ground in place, the 60-cycle hash was completely gone (hallelujah!) and the lightning crashes seem reduced by 90 percent, or so, tho' that is very hard to judge. The signals that were formerly present on MW are simply gone from the lower 2/3 of the band, except for my local 250 watt daytimer on 780 kHz. which is located less than ½ mile from me. Its signal had been reduced from about S-6 to around S-2. There are still a few of the strongest signals present at VERY low levels above 1200 kHz. and on Tropical Bands. This may be the result of a less than perfect ground on the coax braid. I used a single 18 inch long rod into somewhat moist soil. I'm eventually going to significantly improve the grounds of the impedance transformers and the coax shield ground, too… maybe I can drive the last few snakes outta my coax.

Still, the improvement with the two chokes and the simplest grounding of the coax shield is tremendous! I look forward to much quieter and more effective antennas for an investment of under $20.00 per antenna.

IMPORTANT UPDATER: May 2003

Since this first article was published, several people have been somewhat confused as to the actual physical arrangement of the chokes proposed by Bill Bowers and me. Mine are fabricated from small (1" x 2" x 3") plastic (not metal) project boxes from Radio Shack. I use BNC connectors in my coax networks, so I mount a "chassis-mount" male BNC connector on each end of the box and secure the choke in the inside of the box with hot glue. I then attach the braid and center conductor of the RG-174 coax to the normal spots on the backside of each of the BNC connectors and seal up the box. The choke itself is just a continuation of the normal shielded lead-in; the signal goes straight through and never knows that it is whipping 16 or so times around that core. On the other hand, the currents of noise and unwanted signal that reside on the outer shield are thoroughly CHOKED.

Another important point that I should have mentioned in the original article is that grounding the braid/shielding at the center of the lead-in run as Devoldere suggests, (refer to the illustration) is usually best for this whole choke concept to work. However, sometimes quite a lot of noise attenuation is achieved by just using a single choke at the receiver end of the coax. You might want to experiment with this very simple single choke approach before installing the complete system.

TYPE 75 or TYPE J ???

Several months ago, well known mediumwaver Bjarne Mjelde started to order cores from chokes from Amidon and was shocked to find that they no longer made FT-140-75 cores! They make the 140 size (1.4 inches in diameter) in several material types, but not in Type 75. What to do? I contacted co-author Bill Bowers and he investigated. Fortunately, it turns out that Type J cores are virtually indistinguishable from Type 75 cores in our radio applications. Bill ran the following tests on his sophisticated lab gear:

Frequency – kHz	FT-140-75 Impedance Ohms	FT-140-J Impedance Ohms
100	1480	1440
250	4140	3940
500	8430	8290
1000	10210	11770
2000	6320	6950
5000	3900	3970

So, thankfully, we all still have access to cores that will work quite well to get the snakes outta our antennas. **You may use either Type 75 or Type J cores, whichever is available**

Overall Remarks

If one is interested in DXing the Tropical Bands and or the 160 Meter amateur radio band or above, exclusively, the multiple ferrite bead design is feasible, and is less likely to show the impedance anomalies we observed with the ferrite cores. However, if the intent is to DX frequencies as low as medium wave or long wave, then the ferrite beads design would require several hundred beads per lead-in. This would be prohibitive both physically and financially (Amidon charges 14 cents per bead, if bought in 1000 bead lots).

For the generalized case extending to the lower reaches of long wave and extending to 6 or 7 MHz., an approach based on ferrite toroids, each costing about $4.00, wound with RG-174 coax seems by far the most practical. Personally, I'm using FT-140, Type 75 or Type J toroid-based chokes with 15 to 20 turns of RG-174 on them, grounded in the middle, and they work just fine!

Thanks

In the months after the re-publication of this article in the summer of 2003, the authors received comments from interested fellow hobbyists. Several of these were very useful, particularly some of those offered by Chuck Hutton of Seattle, WA. While none of the comments changed any of the basic findings or recommendations, some did cause us to test further and to sharpen and, in some cases, redirect our thinking. As a result, some of the reasoning and comments in the article have been modified as of November 2003. We also appreciate the behind-the-scenes editorial efforts of the indefatigable Nick Hall-Patch of Victoria, BC. We look forward to continuing our efforts in this area and to the results of other hobbyists experimentation. [John Bryant, December 2003]