In practi

SMALL INDUCTORS

Q I am building a filter for VHF. How do I make small inductors accurately to a design value? The standard formula doesn't seem to work. And how do I adjust these coils?

A The 'standard formula' for calculating inductance applies to a single-layer solenoid as shown in **Fig 1**, and is:

$$L = \frac{n^2r^2}{9r+10b}$$

where

L = inductance (microhenries),
n = number of turns,
r = coil radius (in),
b = coil length (in).

This was published by Wheeler in 1928, and although there are many more elaborate formulae, Wheeler's still offers the best combination of simplicity and acceptable accuracy... or at least, it does for inductors resembling Fig 1.

The main problem with the very small inductance values that are used at VHF/UHF (a few hundredths of a microhenry, a few tens of nanohenries) is that the coils have few turns and quite a significant spacing between the turns (**Fig 2**), which is contrary to the basic assumptions of Wheeler's formula. There are several programs available on the web that attempt to deal with these problems in small coils. One of them is *WAIRL* from ALK Engineering [1], which attempts to simulate the practical approach. In practice, you generally have to specify a diameter and use a whole number of turns (Fig 2) and then stretch or compress the spacing between turns to obtain the required inductance. The computer program uses a similar method. Start by specifying a diameter that can be wound on the smooth end of a standard drill. The program makes an informed guess at a suitable whole number of turns, and then goes through a few cycles of trial-and-error until the correct solution emerges. Although *WAIRL* can sometimes be fooled, it will usually give helpful indications of the correct diameter, number of turns and overall length.

A problem with low-value inductors is that the lead inductance can be quite a significant part of the total. Another problem, applying to all inductors, is that they also have self-capacitance which makes the *apparent* inductance change with frequency. Small coils typically used in VHF / UHF filters will typically have a self-resonant frequency of a few GHz, so the effect of self-capacitance is quite noticeable (especially at harmonic frequencies) and should be included in the filter design. In addition, the inductance decreases if the coil is mounted close to the conducting ground-plane of a PC board. For all these reasons, it isn't worthwhile to spend too much effort on perfecting the calculation, because you'll always need to adjust the coil in the situation where it's being used.

A more practical way to make a small coil with a specified inductance is to connect it to a fixed capacitor of known value, calculate the correct parallel-resonant frequency, and then fiddle with the coil until a grid-dip oscillator (GDO) shows the correct resonant frequency. If you are making coils for a PC board layout, the closest approach to the correct results will be to build a little jig that simulates the ground plane, and has a small ceramic chip capacitor connected with the shortest possible leads to the rear side (Fig 2).

So how do you adjust the inductance? Compressing the length of the coil will increase the inductance a little, while stretching the coil will reduce it (gently insert a knife blade between the turns to ease them apart). However, compressing and stretching will only change the inductance by about ±10%; larger changes will involve increasing or decreasing the number of turns, and/or chang-

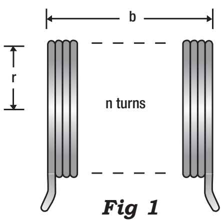
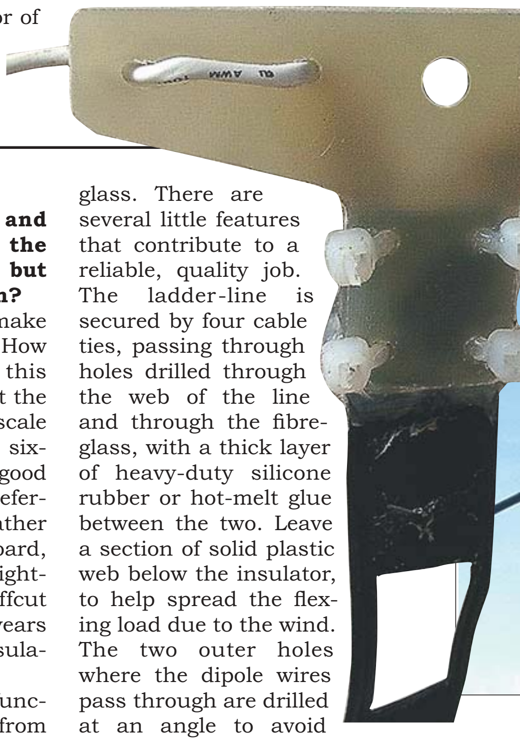


Fig 1

Fig 1: The standard (Wheeler) formula applies best to this kind of solenoid inductor.



ANTENNA INSULATORS

Q I've seen the plastic and ceramic insulators for the centre and ends of dipoles, but what about the DIY approach?

A There are many ways to make these insulators yourself. How much effort you put into this depends on how long you want the insulator to last (the time scale starts at: plastic top from a six-pack = 1 weekend). A very good material is fibreglass sheet, preferably about 3mm thickness rather than ordinary 1.6mm PC board, although that will do for lightweight antennas. I found an offcut of 3mm sheet at a rally some years ago, and have been making insulators from it ever since.

You can make a perfectly functional dipole centre insulator from a double screw terminal block ('choc block') and it will probably last several months before it corrodes inside and/or one of the wires breaks. For a more permanent job, the photograph shows a centre insulator for with 450ohm ladder-line, made from sheet fibreglass. There are several little features that contribute to a reliable, quality job. The ladder-line is secured by four cable ties, passing through holes drilled through the web of the line and through the fibreglass, with a thick layer of heavy-duty silicone rubber or hot-melt glue between the two. Leave a section of solid plastic web below the insulator, to help spread the flexing load due to the wind. The two outer holes where the dipole wires pass through are drilled at an angle to avoid kinking the wire (in practice, drill through at right-angles first, and then gently rock the drill sideways). The dipole wires are soldered to the stripped ends of the ladder-line, and then each joint is completely covered in hot-melt glue. The central hole for the hang-

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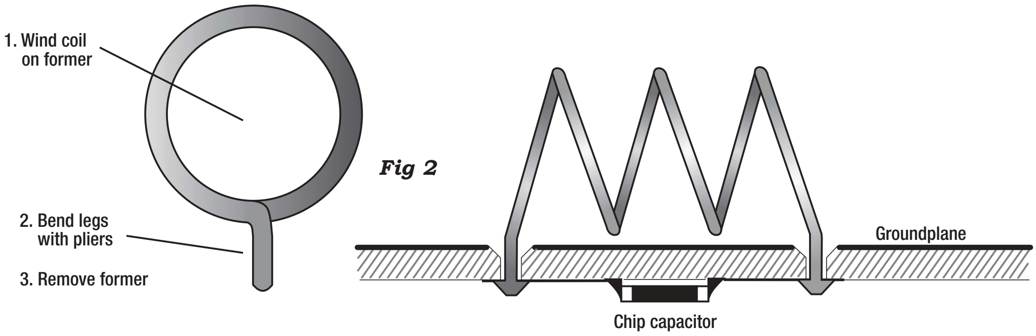

Fig 2

ing the diameter. Replacing the complete coil isn't difficult because it's very quick to wind another (Fig 2). An even quicker way to reduce the number of turns is to snip whole turns out of the middle and then join up with solder. Another good way to see whether you need more or less inductance is to hold either a dust-iron core or an aluminium core next to the coil (a brass bolt will do instead of the aluminium core). Try holding one of these close to the coil on the end of an insulated trimming tool or a wooden cocktail stick. If the inductance moves closer to the target with the dust-iron core, then add more turns, increase the diameter and/or compress the coil lengthwise. If the aluminium or brass moves the inductance in the right direction, then remove turns, decrease the diameter and/or stretch the coil.

These practicalities mean that the best way to use a program like *WAIRL* is to design a close-wound coil for a little more inductance than you need, and then expect to stretch it and/or snip out turns.

When you have pre-adjusted the individual inductors to the correct values, the complete filter will probably be quite close to optimum. Further tweaking will depend on the equipment you have available. If you can make swept-frequency measurements, you don't need further advice from me; but if you can't, you can still do a lot with a GDO, a calculator and an SWR bridge or 'antenna analyser'. The trick with the GDO is to 'dip' various parts of the circuit in isolation. For example, by removing L2 and C3 from the circuit of **Fig 3**, you can test the mesh formed by C1, L1 and C2. Since you know the design values of all three components, you can make final adjustments to L1 to give the calculated resonant frequency for that combination. Then you can repeat the adjustments for L3-C4-C5, and finally for L2-C3 in isolation. The SWR bridge is used to make fine adjustments to the impedance match at the operating frequency, and the trick with the dust iron and aluminium cores comes in very useful here.

Fig 3

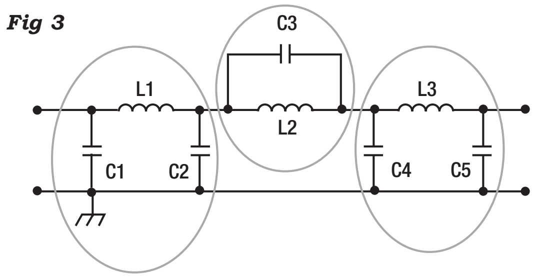

Fig 2: A more typical low-value inductor, also showing a test jig for adjustment in a PC board environment using a GDO.

Fig 3: By dividing a network into isolated 'meshes' (remove other connected components) you can adjust each inductor in position using a GDO.

Left: Fibreglass sheet makes a good dipole centre insulator. Right: 'Band-switching' insulator using wander plug and socket.

ing rope is countersunk on both sides, or else the sharp edges of the fibreglass will chafe through the rope. And that's it! Using a jigsaw to cut the fibreglass, the whole job took about twenty minutes (excluding time for the glue to set) and it should last for years.

End insulators don't have to be large, heavy chunks of ceramic or plastic – they can often be no more than short lengths of strong fishing line. Use monofilament line to shed the moisture, and then you can change to stranded line if you wish. Alternatively, just about anything made of plastic with a couple of holes a few centimetres apart will make a good RF insulator (this really should exclude the traditional coat buttons, because the holes are so close they can easily be bridged by raindrops). Once again, 3mm fibreglass is a good material because of its high strength /weight ratio. You could get two nice little end insulators out of the spare material cut away from the centre insulator in the photograph.

The second photograph shows a more elaborate kind of fibreglass insulator, one that can be bridged by a plug-in connection for band switching. If you don't mind the inconvenience of letting the antenna down, this method has far lower losses than any kind of trap. Instead of the traditional crocodile clip, which will rust badly after a very short time outdoors, I've used a silver-plated wander plug connection that will carry high current, won't fall out and will last for years [2]. The socket is secured to the fibreglass strip by hot-melt glue, which is also used to fix the simple twisted loops in the antenna wires. (Tip: once heated up, the glue gun can be unplugged and used outdoors for several minutes.) As always with fibreglass, countersink the holes to avoid chafing the wires.

NOTES AND REFERENCES

1. **http://www.alkeng.com/wairl.html** – use the link from the 'In Practice' website.
2. **Belling Lee 'OZ' series,** often seen on surplus equipment, and still available from Farnell. Search www.farnell.com/uk for order code 317100 (3mm range) or 317184 (4mm range).

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Many members may wish to try HF operation now that the Morse requirement for access to HF has been formally abolished in the UK. The author offers his thoughts on adding an HF antenna to your existing VHF/UHF antennas.

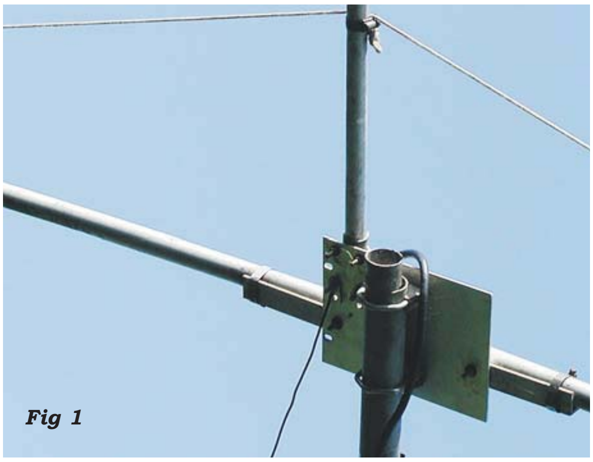

Fig 1

Fig 2

Antennas

Fig 1: Top of the LF antenna mast, showing method of fixing HF vertical. The counterpoise is connected directly to the support plate.

Fig 2: The 14MHz vertical fixed to the top of the LF antenna mast. The counterpoise can just be seen sloping away from the mast to the left.

You may also wish to add another band to your existing single-band HF beam, so what might be the best approach? You could try fixing a dipole using the existing mast as a support, as described in [1], but the existing antenna system might not be suitable for such an arrangement. My antenna system is a case in point. I have a 14m (48ft) mast, which is currently supporting a 136kHz LF antenna and there is no room for any other wire antennas.

ADDING AN HF VERTICAL

You could try a vertical mounted on the existing mast. The late G2XK fixed a 21MHz vertical above his 6-element 10m beam, which gave excellent results. In the past I have added a 14MHz vertical above an existing 21MHz metal quad and this also gave good results.

For a quarter-wave vertical to work, it has to be fed against a ground plane or radials. In both cases described above, the mass of the metal of the beams provided a suitable ground plane.

If the vertical were to be fitted to a mast supporting only a relatively small VHF antenna, would it still work? In the case of my LF antenna, the only metal at the top of the mast is a 3.5m length of aluminium tube that acts as a spreader for the two wires that make up the LF antenna; I was interested in seeing how a vertical would perform in this situation.

The method of fixing the vertical to the top of the mast is shown in **Fig 1**. Originally, there was a short stub mast, which was used to carry nylon bracing cords to prevent the spreaders drooping under the weight of the wire and insulators of the LF antenna. The stub mast was modified by insulating it from the spreader support plate using rubber insulating material and U-bolts. The top of the stub mast was modified so that the vertical element could be plugged in and the joint tightened using a hose clamp. The antenna is fed with 50Ω coax, the centre being connected to the vertical element and the braiding to the support plate.

PERFORMANCE

Although the vertical was known to be a quarter-wave resonant at 14.1MHz, the antenna feed impedance, as indicated by the VSWR, was a long way off 50Ω. The problem was fixed by connecting a quarter-wave-long counterpoise wire directly to the support plate. The length of this wire could be shortened at the insulator (to increase the resonant frequency of the antenna) by folding some of the wire back along itself and fixing with insulating tape.

The 14MHz vertical fixed to the top of the LF antenna mast is shown in **Fig 2**. The top vertical element is only 2.5m long because, when the mast is folded over, that is the distance from the top of the mast to the end of the garden. The element is resonated using a centre-loading coil. Lack of space precludes a description of the loading coil, but it is described in [2].

The coax feeder to this antenna is rather long – some 60m – so it was important to get the VSWR down as low as possible to minimise signal loss.

First impressions indicated that the performance of this vertical was very similar to my two-element minibeam mounted on the chimney of the house at about 10m (30ft) high and fed with 20m of coax. The height of the vertical feed-point is 14m (48ft), but this height advantage is probably partially cancelled by the long feeder.

The DX performance of this vertical seemed quite good, having a slight advantage on long DX paths, although the noise level on the vertical was slightly higher.

CONCLUSION

If you are mounting a vertical on a large existing metal structure, it should work well. Originally, I was of the impression that the mast itself would be sufficient but, in my case, this proved not to be true. The length (height) of the mast might be critical, but I was unable to test this.

If you mount an HF vertical above an existing small antenna, such as a VHF / UHF beam, the addition of a counterpoise seems to do the trick, and has the advantage that it can be used to adjust the antenna's resonant frequency. ◆

REFERENCES

[1] ***Backyard Antennas,*** RSGB Sales
[2] ***The Amateur Radio Mobile Handbook,*** RSGB Sales