Antenna Workshop

John Heys G3BDQ helps you with loading wire antennas, to make them work on lower bands.

The physical length of resonant Hertzian or Marconi antennas is largely determined by the design frequency. In most cases, dipoles (Hertzian) and quarter-wave (Marconi) antennas intended for use on the higher frequency Amateur Radio bands can be installed in an average sized garden, but effective antennas for the bands below 3.5MHz, can be difficult to accommodate in urban locations.

The radio pioneers worked hard to extend the range of their primitive equipment, but soon discovered some problems when considering ship-borne antennas. These antennas were essentially restricted height Marconi designs so, to achieve resonance at the low frequencies then used, the engineers had to resort to some kind of loading to bring the antenna to resonance.

Smaller Vessels

Achieving resonance was a particular problem on smaller vessels. Capacitive and inductive loading techniques were used, as 'linear loading' was not then known. The convenience of a shorter antenna achieved by loading has a cost and there will always be some reduction in the antenna's efficiency. Perhaps more importantly, there's also a reduction in the useful bandwidth of the antenna.

For fixed frequency work, a reduction in bandwidth is not serious, but Radio Amateurs, generally like to operate across all, or most of each Amateur band. To use the whole band, we sometimes have to resort to 'force feeding' a short antenna by using an antenna tuning unit (a.t.u.) or impedance matcher.

Any antenna matcher will introduce a power loss, which can be as high as 20% in some cases. A badly designed a.t.u. may appear fine and indicate a low s.w.r. and yet lose more than 50% of the transmitter power. **If your a.t.u. gets hot, it is a 'loser'**.

Capacitive Loading

The technique of loading, sometimes being called 'top loading', was developed quite quickly. Prime examples of this type of loading may be seen in photos of the ubiquitous 'twin wire' ships' antennas. An illustration of a typical two wire capacitively loaded antenna is shown in **Fig. 1(a)**.

Capacitive loading uses the inherent self capacitance of a wire, which is determined by the wire diameter and its height above ground. A wire of one millimetre diameter and 10m above ground will have a self capacitance of approximately 6pF per metre of length when running vertical and around 5pF per metre if it runs horizontal.

When two horizontal wires are used as in Fig. 1(a), a useful increase in capacitance can be gained. When the wires are closely spaced, at let's say one millimetre, the capacitance increase over a single wire will be about 4%. When the wires are separated by 100mm the increase grows to 40%. Where wires are spaced one metre apart the increase can be around 70%.

Further Increase

If the spacing (S) is further increased to two metres, there can be a capacitance increase of almost 100%. Doubling the diameter of the wire quadruples its weight, but only increases the capacitance by about 7%. So, it's better to use a pair of thinner wires, positioned this way as the wires are in phase and the radiation will match that of a single wire and be horizontally polarised. The vertical downlead though, will show vertical polarisation.

Another popular antenna has been the 'T' as shown in Fig. 1(b) which has just a single top wire or pairs of wires. The top section of the 'T' has little or no radiation, as the sections L2 and L3 are in anti-phase. Most of the radiation will be from L1 and thus vertically polarised.

A variant design, shown in Fig. 1(c), has a number of horizontal wires L_H going in various directions that add considerably to the overall capacitance loading. This configuration is how I capacitively load my 85m long wire to make it more effective on 136kHz. It works well on all the h.f. bands and has even given me lots of DX contacts on 50MHz.

Inductive Loading

Adding an inductance in series with a wire will increase the electrical length of the wire, thus lowering the wire's resonant frequency. The positioning of the inductance will decide its loading effect. The effect for any inductance will be greatest if it's situated at the bottom, or feed end, of a 'short' wire.

The further an inductance is placed from the feed-point, the smaller will be the loading effect and to maintain resonance the coil's inductance must increase greatly to compensate. A very large inductance will be required if the loading inductance is at the far end of the wire where it's likely to be heavy and be very moisture sensitive.

A coil at the 'inner' end of the wire may be actually inside the house where it can be tapped to the correct tuning inductance and will not suffer the vagaries of the weather. This arrangement is popular with 'Top Band' (1.8MHz) enthusiasts who can 'load up' their relatively short antenna wires.

Inductive loading is not only useful with Marconi systems, but can also be employed to electrically 'lengthen' Hertzian dipoles. **Fig. 2(a)** shows a half-way dipole with loading coils positioned close to the feed point. The inductors L when in this position may be small but will carry high levels of r.f. current and unless made with heavy gauge wire, can have quite high losses.

Useful Compromise

Inductors at the ends of the dipole legs, Fig. 2(b), must be very large in inductance and may prove awkward to use in real outdoor situations. A useful compromise may be reached, when the loading inductors are

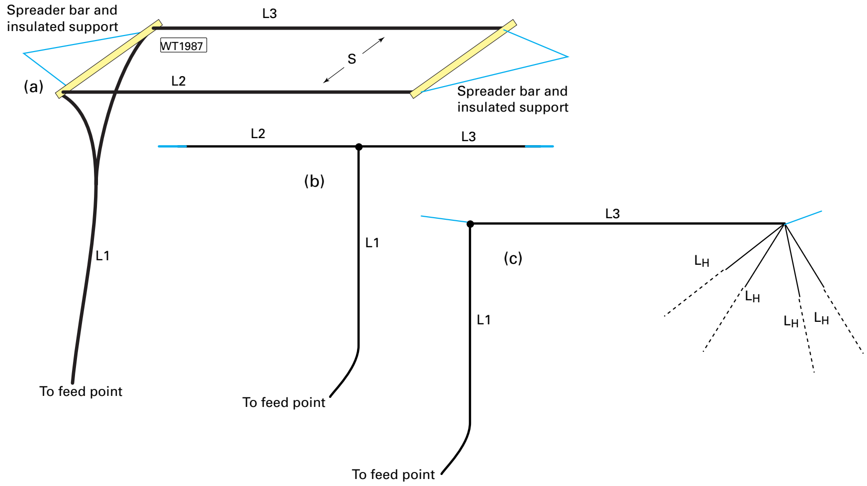

Fig. 1: Three antennas using capacitive loading. The twin wire system in (a) was widely used on ships and the spacing between the wires 'S' can be arranged to almost double the self capacity of a single wire. See text for more detail.

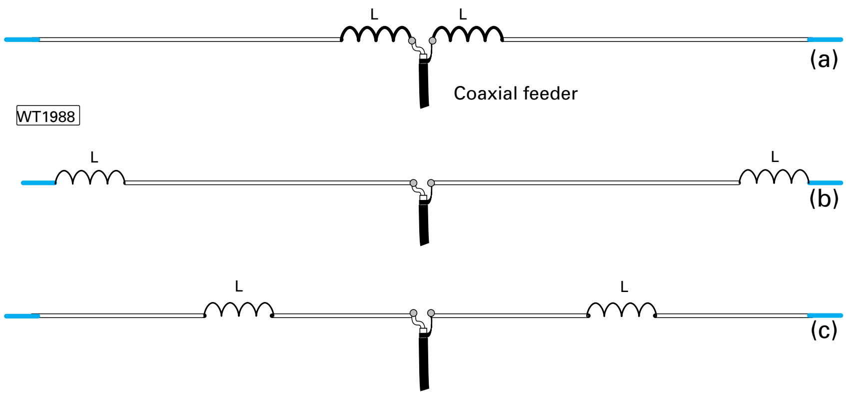

Fig. 2: The most effective position for the loading coils L is half way along the dipole legs (c). This results in an effective half sized antenna with little power loss. See text for more detail.

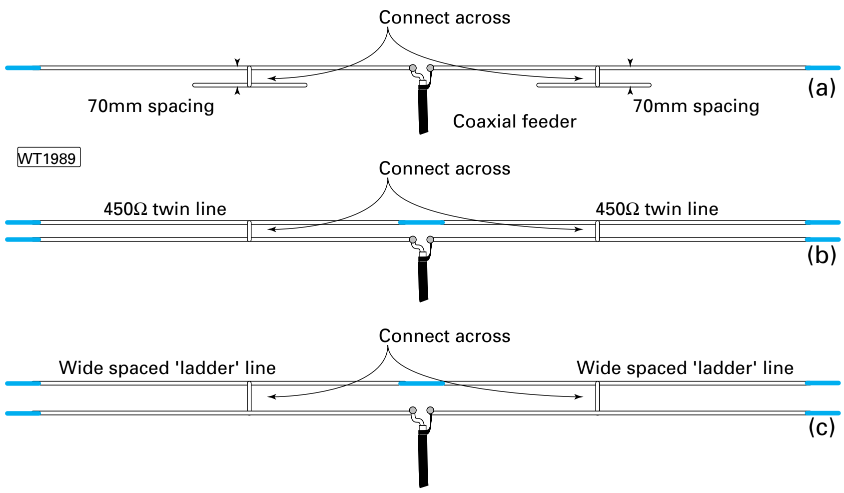

Fig. 3: Linear loading of dipole antennas. The loading wires can be above or below the dipole elements and they do not radiate. See text for more detail.

positioned half way along each leg, Fig. 2(c), of the dipole.

With a mid-point loading coil, the dipole may be shortened to half the 'normal' length for the frequency, with just a modicum of power loss. The inner 50% of the dipole radiates 71% of the total power so, the use of inductive loading in middle of each wire, will make it possible to have an effective but half sized dipole.

The mid-point arrangement requires a pair of inductors, each with a reactance of about 950Ω at the operating frequency. This equates to inductances of 40µH and 25µH respectively on the 3.5 and 7MHz bands. Good weather proofing of the coils and the use of at least 1.5mm diameter wire for the windings is recommended.

Linear Loading

It's difficult to find practical information regarding the method of linear loading. I have quite a large library of antenna books, but very little useful information on linear loading can be found. So, I decided to try out a few experiment antennas to discover some of the essential parameters involved.

My first model was similar to that shown in **Fig. 3(a)**. An indoor dipole was cut to resonate on 29MHz and a pair of 'T' sections (which do not radiate) each 447mm in length were connected to the dipole legs at their centres. Each T section was spaced 75mm below the dipole wires. I then found that this new form was resonant on 28MHz, a frequency shift downwards of 1MHz.

For my second experiment, I used 450Ω impedance commercial feed line for both the dipole and the loading wires Fig. 3(b). The loading wires were made the same length as the dipole legs themselves. This arrangement changed an antenna that would have appeared to be resonant at 28MHz to be actually resonant at 24.2MHz.

Deducing that the spacing between the antenna and the loading wires related to the wire spacing shown in Fig. 1(a), my next experimental antenna was made with home-brew wire ladder line Fig. 3(c). I initially made the simple dipole (without the loading wires) to resonate on 28MHz.

I then created the ladder line sections to the same lengths. And with these connected, the antenna's resonant frequency went down to 22MHz. This means that an antenna using linear loading could be made much shorter than a simple dipole.

More work is needed to evaluate and determine the parameters of useful linearly loaded wires, for there are several variables; the radiator length, the length of the loading wires and the spacing between these and the dipole elements.

My Conclusions

My conclusions based on the observations made regarding the three methods of loading will also equally apply to vertical antennas ... whether used as single wires or short rods. However, it must be emphasised that full sized l/4 Marconi, or l/2 Hertzian antennas will always outperform a short load antenna.

It's only when space is limited or awkward in shape that antenna loading should be contemplated for this invariably introduces losses in power and a restriction of bandwidth. However, to keep all this in perspective we must remember that a 50% power loss will result in just a 3dB (half one 'S' point) reduction in signal strength at the distant receiver!

So, if you have less space - load away, you have nothing to lose, but much to gain!

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