Antenna Matching Networks: why do we need them?

Transmitters and receivers are designed to work into a specific load impedance. In most cases this is 50 Ohms. We spend a lot of time optimising our antenna systems to make them "look like" 50 Ohm loads. In the case of some antennas, they are, by design, roughly 50 Ohm loads. A half-wave centre-fed dipole is a good example of this where, depending on its environment and how the wires are arranged, it will present a 50 Ohm load. It would be possible to only use antenna like this and thus avoid using antenna matching networks but to do so would severely limit the antenna options available.

Many antennas have different load impedances, For example wire loops of various sorts (quads, delta-loops etc) often have a feed-point impedance of around 120 Ohms. Such antennas are usually matched at their feed point to 50 Ohms to allow them to be fed with 50 Ohm co-axial cable. Perhaps the most widely used multi-band antenna is a doublet fed with open wire line. This type of antenna often has both a very high VSWR at its feed-point and a presents widely differing impedances across the HF spectrum at the end of the open wire line. To use any of these antenna types, antenna matching networks are essential.

It would be wrong to assume that antenna matching networks necessarily introduce excessive losses into systems; indeed sometimes that are used to reduce losses. How so? Imagine a radio system with a dipole antenna that is remote from the transmitter; if it is many wavelengths away as is often the case in professional radio systems, it may be more efficient to match it to the impedance of open wire line (450-600 ohms), use that for the long feeder run and then match back to 50 Ohms; two antenna matching networks being used to reduce losses as the losses due to a long length of open wire line are much less than those of an equivalent length of co-axial cable.

Simple antenna matching networks

For temporary or portable working a simple "long wire" is often a great way to get on the air. Some lengths of wires have been gifted with almost magical qualities in amateur radio circles. These lengths have often been chosen to allow relatively easy matching using simple matching networks. An antenna matching network consists of components that have been selected to transform the impedance presented at the end of the antenna to 50 Ohms. If the impedance at the end of an antenna was resistive a simple impedance matching transformer of some sort could be used. impedance matching transformers are wide-band matching networks, often best suited to matching resistive loads. However, the impedance at the end of a long wire is usually reactive, that's to say it has a complex impedance that can be described as having a resistive component and some capacitance or inductance. The impedance will also vary with frequency, thus narrow-band matching networks are often used.

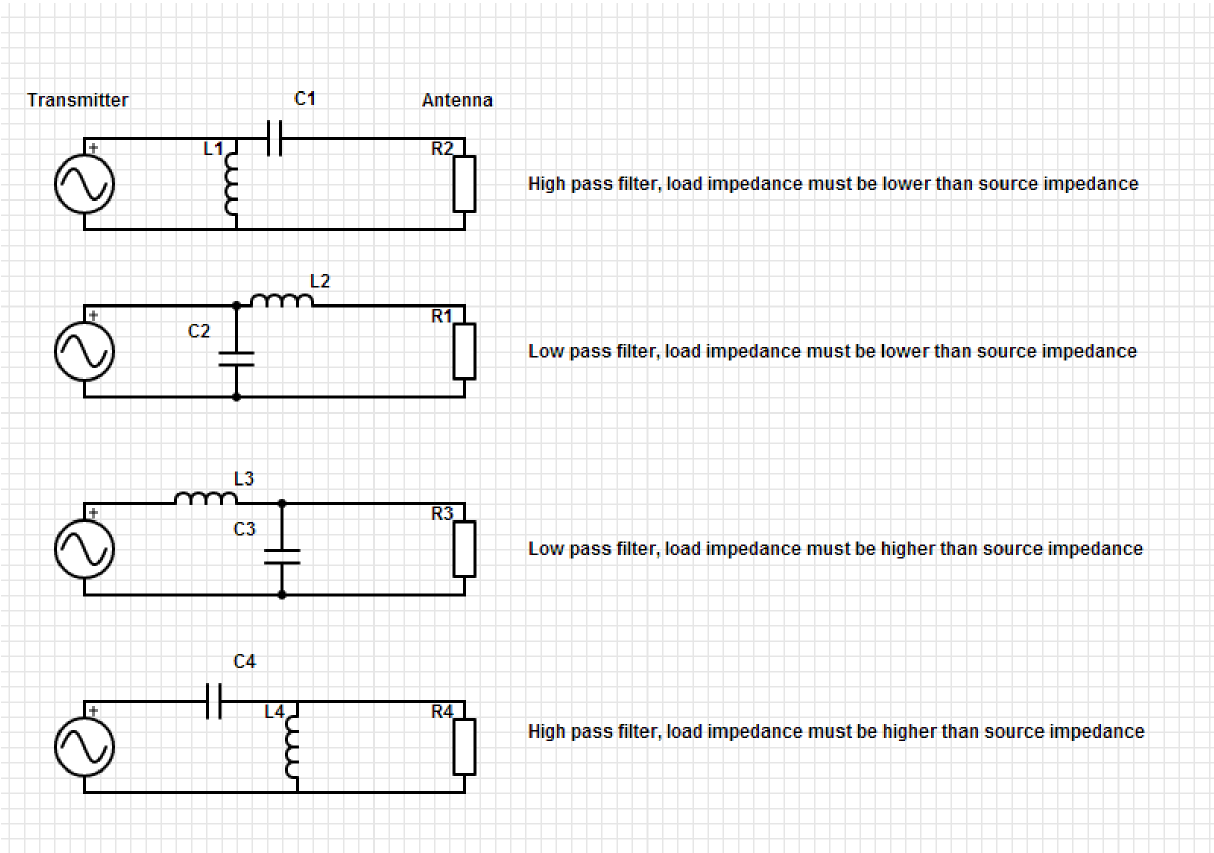
In some (special) cases it may be possible to match an antenna using just an inductance or a capacitance but in most cases a combination of inductance and capacitance will be needed to provide the necessary impedance transformation in an antenna matching network.

The simplest and most widely used antenna matching network is the L network. In this case we are considering L networks that consist of a capacitor and an inductor. This is a narrow-band network in that if you change band, the network will need to be adjusted to suit.

There are four ways in which these components can be configured and each of the four ways has slightly different characteristics.

They can:

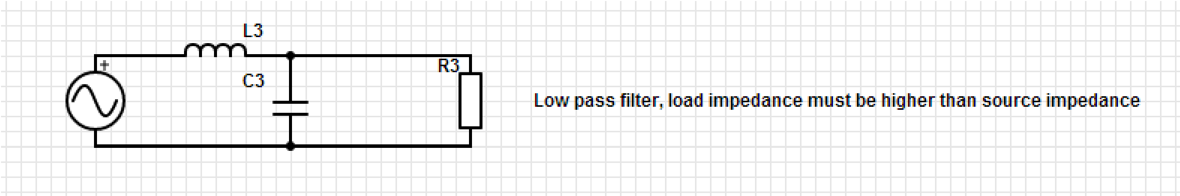
- be low-pass or high pass networks
- provide a DC block between the source and load or not
- match impedances higher or lower than the source impedance.



Deciding which is most useful depends on what you are doing, but in most cases:

- the load impedance of an antenna will be higher than the source impedance (i.e. greater than 50 ohms);
- the provision of a DC block is not an important consideration; and
- a low pass filtering action is preferable to a high pass filter as it provides some small level of attenuation of harmonics.

So this is generally the most useful of the L networks.



There are actually four other L networks, two consisting of two capacitors and two consisting of two inductors. These are less commonly use as they provide a smaller matching range than the L networks discussed above.

Different antenna matching networks

The L network will theoretically match any impedance. However, in some cases the component values become impractical. It is for this reason that antenna tuners sometimes use more complex networks to achieve a wider matching range. These more complex networks can be harder to adjust.

The Tee network provides matching for impedances that are higher or lower than the source impedance but tends to be configured as a high pass filter. In theory this type of network can match any load impedance although to match more extreme load impedances requires unrealistic L and C values. In this respect it has the same limitations as the L network. The T network usually has three controls to adjust making it a little more complicated to use.

The Z match is a version of the L match that does not require a tapped inductor. Again, the matching range is limited by the component values. The Z match usually has just one control to adjust so if it's suitable for your antenna it's easiest to use.

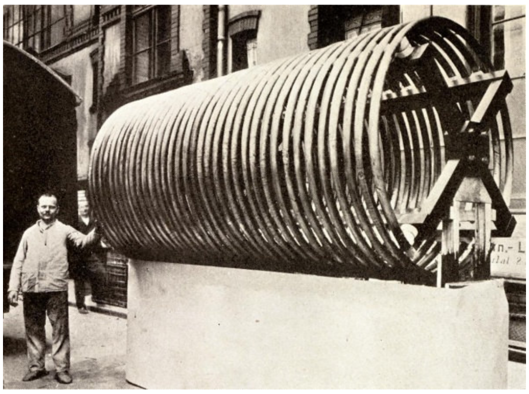
Extending the matching range of a network

All practical antenna matching networks have a limited matching range. They have a finite range of inductance and capacitance and usually have a fixed network topology. The matching range of antenna tuners can be extended by attaching an external network that will transform the impedance of an antenna system into the matching range of a simple antenna tuner. One way of doing this is by adding a 4:1 matching transformer between the antenna and the tuner. This reduces the range of impedances seen by the tuner and will allow matching over a wide bandwidth. Of course there is an additional loss associated with the matching transformer and this tends to be higher in high impedance systems.

Losses in antenna matching networks

There are a number of potential areas of loss in antenna matching networks. Capacitors tend not to be very lossy provided any sliding connections (found in most variable capacitors) have a low resistance. Inductors will have resistive losses. These are accentuated by the fact that RF flows only on the surface of the conductors (it penetrates only slightly), thus coils in high power antenna tuners are frequently silver plated. The actual loss of an antenna matching network tends to vary depending on the impedance of the load to be matched. Matching network loss can be measured by matching the load impedance with one network and then connecting another identical network to it to match back to 50 Ohms. You can then measure the total loss and half it to give the loss through the matching network.

Commercial antenna tuners are often in metal boxes. These boxes can reduce the Q of the tuning inductor and can even increases losses.



Some antenna tuners have large loading coils

Where to put the antenna matching network?

The best place for an antenna matching network is usually at the feed-point of the antenna. This allows the use of a defined-impedance transmission line between the antenna and the transmitter. There are exceptions though: in the case of a doublet fed with open wire line, the line losses are so low that the high VSWR at the feed-point of the antenna does not give rise to excessive feed-line losses and so the tuner can be at the end of the open wire line. Another exception is where an antenna tuner is used to increase the bandwidth of an antenna so that the band edges can be used. The most common example of this is when a co-ax fed 80m dipole is being used and coverage across the whole band is required. In such a case it's fine to have the matching network at the end of the co-ax because:

- the VSWR is moderate
- the excess line loss will be low due to the low radio frequency.

For these reasons, internal "antenna-tuners" in radios intended to be used in the shack are not as flexible for use as external tuners.

SOTABEAMS

SOTABEAMS makes a range of antenna tuners for portable use.

www.sotabeams.co.uk

References

Electronic Applications: Smith Chart, Philip Smith, Noble Publications