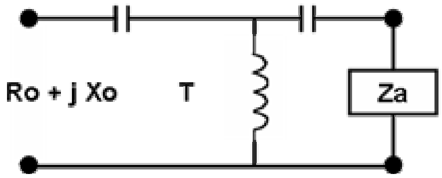
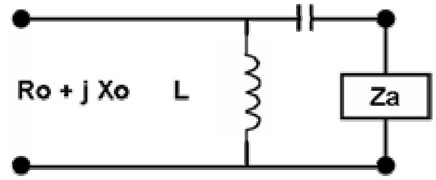
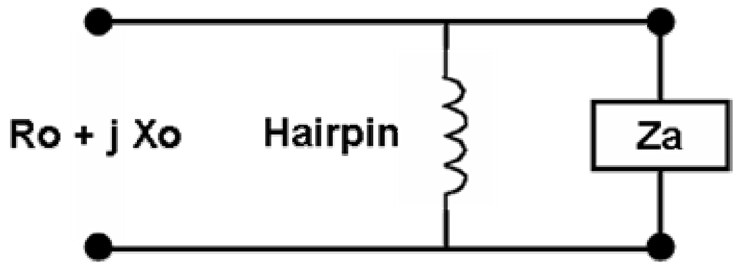
Subtleties of the Hairpin Matching

A number of matching networks have been employed such as the T, the L and the simplest the "Hairpin" as shown here.







For the T and L, the capacitor/inductors can be interchanged as needed, the hairpin is, by definition, just a single inductor. While the conventional configuration is indeed a single hairpin shaped loop, any inductor, such as a coil, is equally good from an electrical perspective. For lower frequency applications, a coil is pretty much required to get compact inductance.

The obvious beauty of the hairpin is simplicity since most of us have access to wire. The typical application for antennas is matching to a standard feedline impedance when the raw antenna shows moderate capacitive reactance and the resistive component is less than the desired feedline impedance.

Given a target feedline impedance of Ro, and a raw antenna impedance of Za=Ra+jXa, Xa being negative, the condition to be met, if possible, in picking a shunt inductive reactance of XL is

$1/(Ro+j0) = 1/(jXL) + 1/Za$

for a perfect match. This perfect match is not generally possible for arbitrary Za and Ro. However, it is always possible to find an XL that will yield an output impedance with a resistive component of Ro for any Ra. But this will be for only one value of Xa.

It is pretty easy to show that the requirement is

$Xa = -[Ra(Ro-Ra)]^{1/2}$

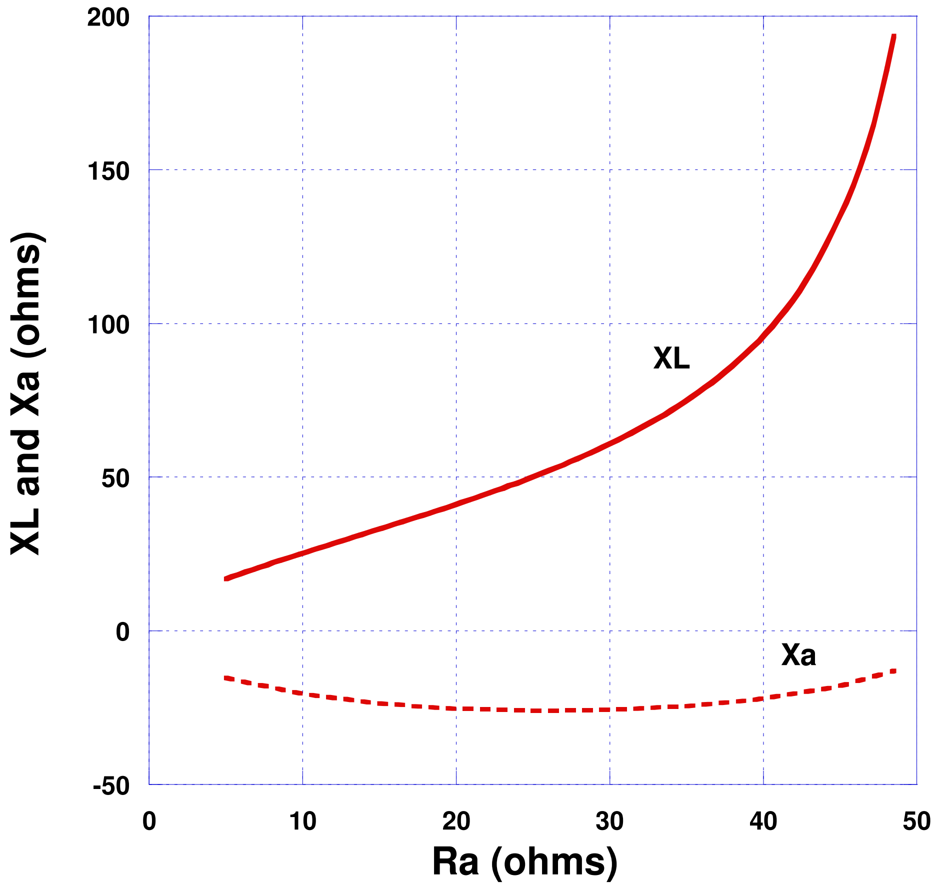
so then

$XL = -Za^2/Xa = -(Ra^2 + Xa^2)/Xa$ which uses the above Xa. This sunstitution provides

$XL = (Ra^2 + Ra(Ro-Ra)) / [Ra(Ro-Ra)]^{1/2}$

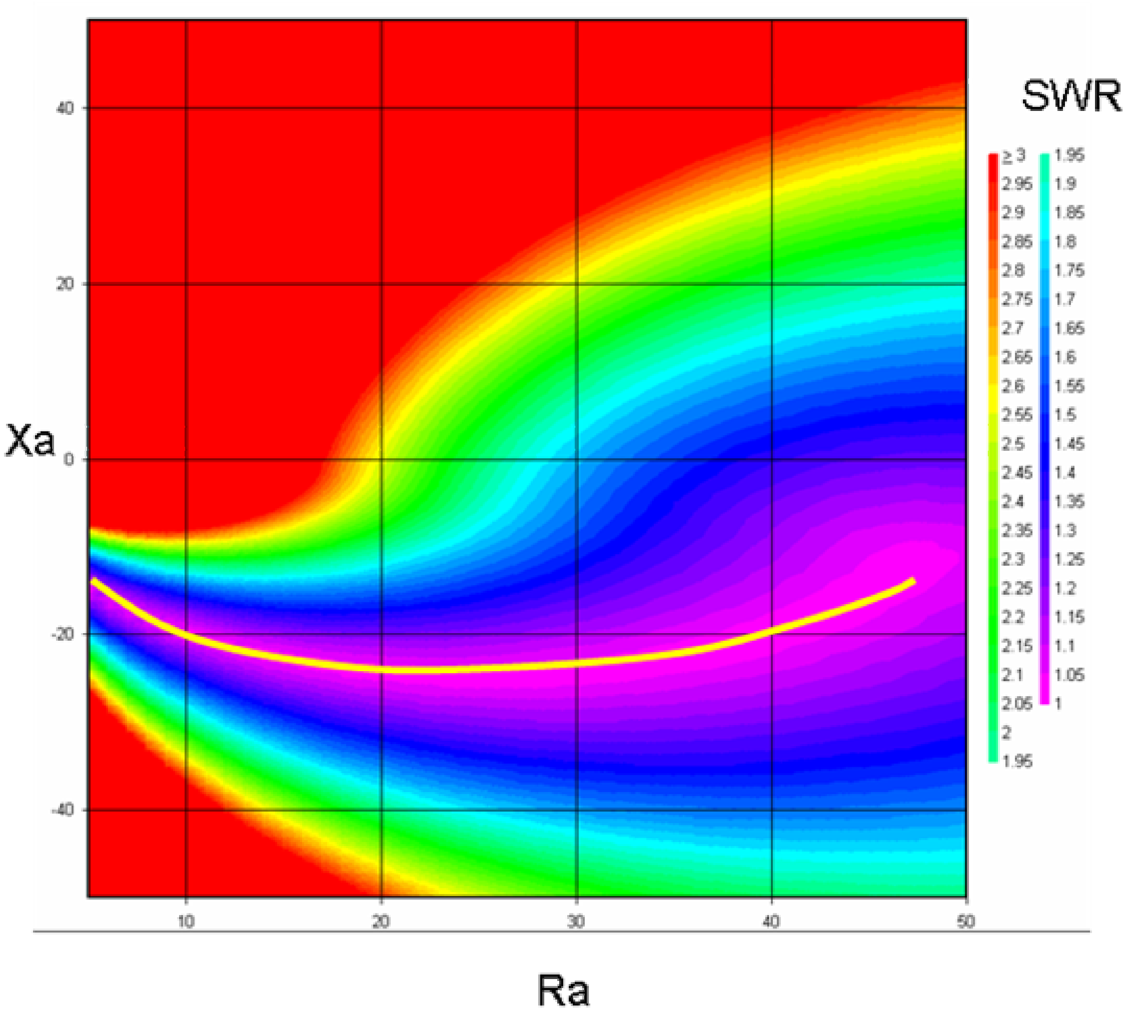
The plots of XL versus Ra in the ARRL Antenna Book (21st Ed, Figure 15 page 26-12) can be reproduced with this relation. You may note that the x-axis of that Antenna Book plot is mislabeled as Z_A - it should be the resistive component of Z_A that is called Ra here.

Below is plot the results for the Ro=52 ohm case, along with the corresponding Xa value needed for a perfect match. Note that the value of Xa does not vary much and is ~ 20 ohms.

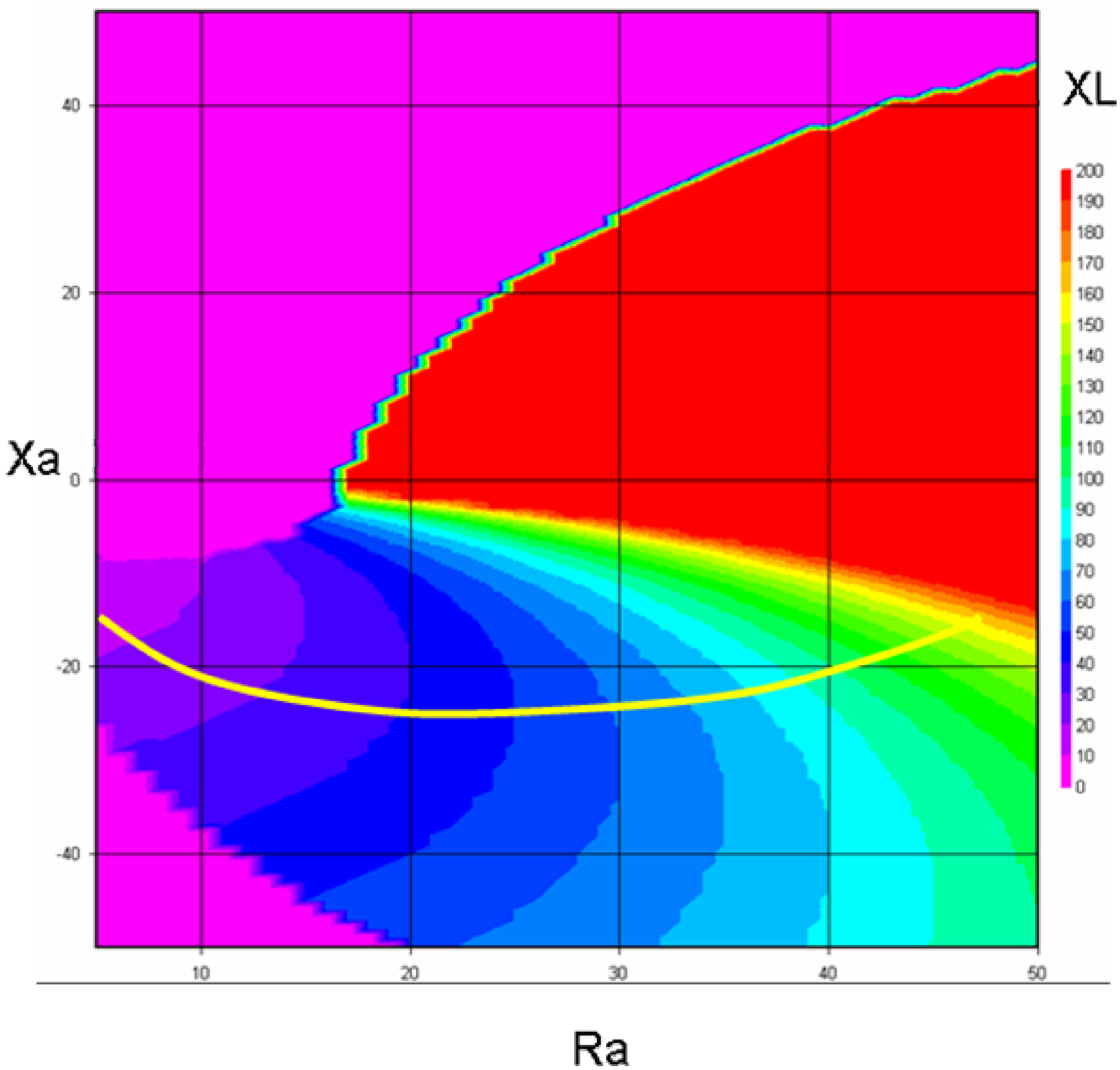


An alternate way of displaying the results that provides a indication of how close you need the Xa to be to its ideal value is to show as a contour plot the SWR available by the hairpin match for any (Ra,Xa) combination followed by the XL values that are required for this combination.

A contour plot of SWR for the Ro=50 case over a wide range of Ra and Xa is given first. The yellow line shows approximately where an SWR of 1 is available.



The corresponding contour plot of XL for the same Ro=50 case is given next.



Given Ra and Xa, you might use the first contour plot to determine the best SWR available. The second plot would then indicate the needed XL. If you find that the SWR available is not acceptable, you may be able shorten or lengthen the antenna driven element to get a better pair of Ra and Xa values that will support a closer hairpin match.

It is left as a problem for the student to verify that the SWR has been correctly computed from Ro, Ra, Xa and XL.